Circular No. 778

Red Pine Management in Minnesota

F. H. EYRE and PAUL ZEHNGRAFF, Silviculturists

Lake States Forest Experiment Station
Forest Service

UNITED STATES DEPARTMENT OF AGRICULTURE

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By F. H. Eyre and Paul Zehngraff, *silviculturists,*[2] *Lake States Forest Experiment Station,*[3] *Forest Service*

POTENTIALITIES OF RED PINE

The present forests of red or Norway pine (*Pinus resinosa*) in Minnesota are mostly second growth. They do not cover large areas. Yet, under management, they are as productive, acre for acre, as any in the State. Because it is long-lived, comparatively free of diseases and insect pests, makes fairly rapid growth, prunes itself well, and produces straight, sound, high-grade timber, red pine is probably the best general-purpose tree for the Lake States. Due to these characteristics and its adaptability to sandy and gravelly soils, of which there are large areas in need of restocking, red pine has been planted extensively—more so in Wisconsin and Michigan than in Minnesota—and the reforested area is increasing yearly. The importance of red pine will therefore increase.

It is not likely that stands laboriously restored by planting will be indiscriminately slashed off as they become merchantable. Reliable information on their management will be needed. What better place to look for information than to the natural stands of the region? Most of those that have had the benefit of management are in Minnesota, hence the data presented are mostly from that State. Actually, however, the results will have application in a large measure anywhere in the region.

Experience in the management of red pine dates back over 40 years. It began in 1902 with the passage of a congressional act [4] which established the Chippewa (Minnesota) National Forest and prescribed the leaving of seed trees in the original logging. As the forest areas of the State became more accessible and as knowledge improved, advances were made in the management of red pine. Instead of leaving only seed trees to restock cut-over areas, attempts were made to

[1] Received for publication December 17, 1947.

[2] The authors are particularly indebted to C. E. Knutson, formerly Forest Supervisor, Chippewa National Forest, for his cooperation in trying out various cutting experiments, and to E. G. Cheyney, T. Schantz-Hansen, H. B. Wales, H. H. Chapman, William Heritage, W. M. Robertson, G. A. Mulloy, F. G. Wilson, H. H. Richmond, J. E. Donery, W. G. Wahlenberg, H. E. Ochsner, G. A. Pearson, Richard Delaney, and J. H. Buell for their helpful comments in reviewing the manuscript or portions of it.

[3] Maintained by the Forest Service, U. S. Department of Agriculture, at University Farm, St. Paul, Minn., in cooperation with the University of Minnesota.

[4] Morris Act of June 27, 1902.

practice a simple form of the shelterwood method which removed the forest in two separate cuttings. Later, with the opening up of markets for mine timbers, piling, box bolts, small sawlogs, pulpwood, and other products, management of younger stands has been carried forward on an increasingly intensive basis.

The results of stand management of red pine—by leaving seed trees, by two-cut methods, and by more intensive forestry which provides for frequent light thinnings and intermediate cuttings—both on the Chippewa National Forest and elsewhere in Minnesota, have been assembled here. The main objective of this publication is to draw together in one place the most complete and reliable information available on the management of natural red pine stands. The last general bulletin on red pine (*38*)[5] was published in 1914. Some parts of that publication are as accurate today as when written, but there has been a considerable extension of knowledge on management. The need for an up-to-date treatment of the subject is therefore obvious. Information gathered from experimental cuttings, and results of larger tests and demonstrations on experimental forests as well as general administrative experience on private and public lands, have been drawn upon freely to form the basis of this report.

PAST AND PRESENT FORESTS

Red pine was an important component of the famous pine forests aggregating nearly 6 million acres which were originally distributed throughout northern Minnesota. This magnificent old-growth forest of pine (figs. 1 and 2), commonly thought of as almost entirely eastern white pine (*Pinus strobus*), has been reported to have been actually as much as 30 percent red pine (*4*). On the better soils red pine was a minor constituent of the white pine and hardwood forest types. On the sandy and gravelly soils it was often found in pure stands or in mixture with jack pine (*Pinus banksiana*). On the poorest land it gave way almost exclusively to jack pine. Stands on typical red pine sites averaging 30,000 board feet per acre extending over tracts as large as 40 acres are of record on the Chippewa National Forest. A 52-acre tract of virgin timber carefully estimated in 1936 in northern Itasca County ran 40,000 feet per acre, over 80 percent of which was red pine.

Rapid and complete liquidation of most of the old-growth pine has taken place (fig. 3). The high quality of the timber and gentle topography of the region, which makes for easy logging, has speeded such a course. Following cutting, devastating fires swept the country and destroyed advance growth left after logging. Fires also brought about the spread of jack pine at the expense of red pine (*13*).

Other areas after cutting came back to aspen (*Populus tremuloides* and *P. grandidentata*) (fig. 4), paper birch (*Betula papyrifera*), or to northern pin oak (*Quercus ellipsoidalis*). On red pine sites aspen and birch develop poorly, and northern pin oak is of little account wherever it grows. Some lands reverted directly to brush and grass; other lands formerly in red pine were cleared of stumps and farmed for a time, but later abandoned. The net result of all this has been a great contraction of the formerly widespread red pine type of forest.

[5] Italic numbers in parentheses refer to literature cited, p. 66.

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FIGURE 1.—Heavy virgin stand of red pine. Pike Bay, Chippewa National Forest, Minn.

F-392261

FIGURE 2.—Virgin stand of red pine in which reproduction has become established in natural openings. Pike Bay, Chippewa National Forest, Minn.

F-423353

FIGURE 3.—Clear-cutting in virgin red pine. Itasca County, Minn., 1942.

F-432995

FIGURE 4.—Seed-tree type of cutting on good site. The stand has reverted to aspen and birch. Itasca County, Minn.

Despite past abuses some valuable red pine forests are present today. How did this happen? There is, of course, a remnant of old growth still present that originated many years prior to the period of extensive exploitation. These stands have survived numerous fires as evidenced by the butt scars so common in older timber. The same is true of the larger second growth which existed as young stands at the time of extensive lumbering. A considerable area now classed as poles came in about the time the original cutting took place and for some reason or other escaped fire while very young and highly susceptible to injury.

Some of this timber had its origin as advance reproduction under the virgin forest. As old stands thin out, it is very common for young seedlings to spring up in the openings (fig. 2). If they escape fire, these seedlings develop rapidly as soon as the old timber is removed. A good seed year coincidental with logging has been responsible in many cases for the restocking of the land. In some instances fire before logging has actually been of benefit by clearing off the vegetation and thus preparing a seedbed a year or two before a heavy fall of seed. In such cases abundant reproduction may occur (fig. 5). Seed trees left after logging have also accounted for some of the regeneration.

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Figure 5.—Red pine stand 250 years old. Reproduction has become established as result of a surface fire and subsequent light cuttings. Pike Bay, Chippewa National Forest, Minn.

The latest statistics [6] on the extent of present red pine forests show the type to cover 180,000 acres in Minnesota. Red pine is also an important associate of the jack pine and the white pine types, a

[6] Cunningham, R. N. Revised forest statistics for the Lake States 1945. U. S. Forest Service, Lake States Forest Expt. Sta., Sta. Paper No. 1, 27 pp. 1946. [Processed.]

fact not clearly brought out by general statistics. Although the red pine type is now restricted in area for reasons previously given, the area is increasing through reforestation.[7] Moreover, red pine stands are generally better stocked than other upland conifers, and better than most hardwoods. Their importance is thus much greater than the area of the type would indicate.

Aside from the significance the present natural stands have in pointing out the excellent forestry possibilities of red pine, they are of considerable economic value for the timber they now contain. The average volume of saw timber per acre for the entire red pine cover type in Minnesota is 2½ times that for jack pine and 10 times that for aspen-birch, two of the most common types, according to the Forest

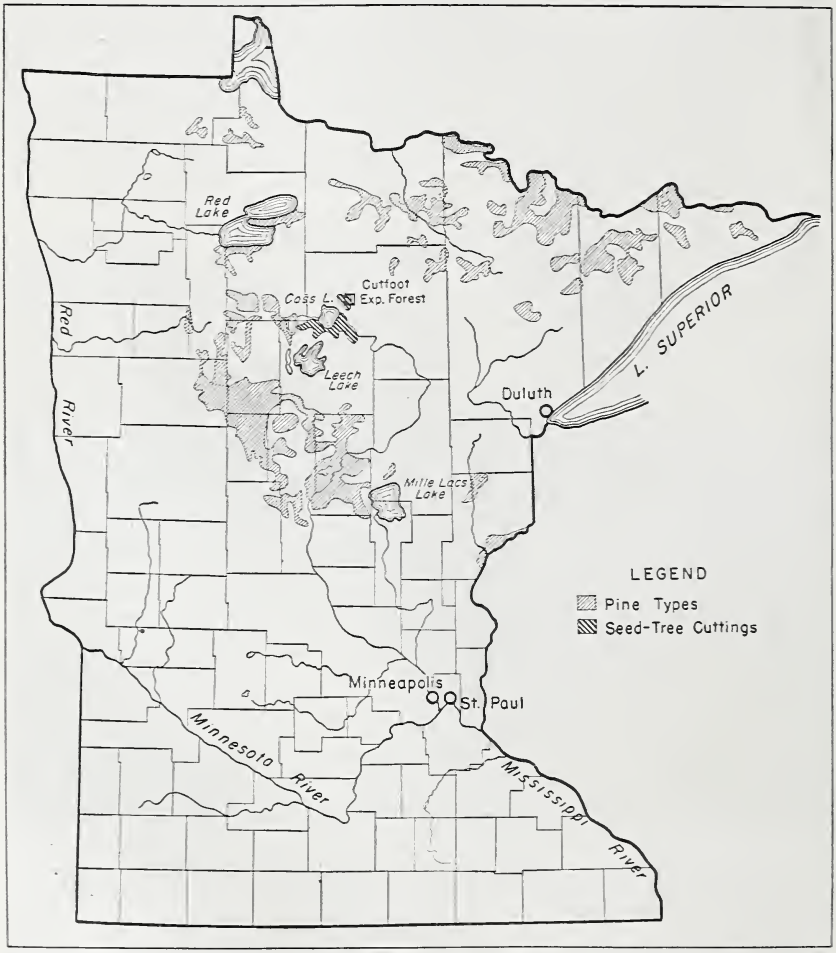

FIGURE 6.—Location of principal pine forests in Minnesota. Within these areas red pine occurs in scattered stands.

[7] Some 50,000 acres have been planted to red pine in Minnesota and 450,000 acres in the Lake States, probably 65 percent of which would be classed as successful plantation according to data compiled by P. O. Rudolf. Part of this planting is too recent to be included in the area statistics.

Survey. Old-growth saw-timber stands average about 10,000 board feet per acre and second-growth stands nearly 6,000 feet. Cordwood stands are generally understocked and average 8.7 cords per acre. These are large-scale averages and by no means represent potentialities under management. The present stands, although scattered throughout the northern part of the State, find their greatest concentration along the upper reaches of the Mississippi and in the headwaters basin of that river (fig. 6).

Such are the stands which are available for management. The volume data presented are broad Forest Survey averages and at least half of the stands are actually better than the figures portray. The better stands naturally offer better opportunities for management. On the other hand, the possibilities of bringing the poorer stands gradually to a good state of productivity through careful handling should not be overlooked. Unfortunately many of the young stands are being prematurely clear-cut for pulpwood or low-quality lumber. Such cutting more frequently than not occurs at an age when growth rate is at its peak. Treating young red pine in this manner results in serious economic loss because highest quality and value have not yet been reached. Better methods of management are outlined in the pages to follow.

SEED-TREE CUTTINGS UNDER THE MORRIS ACT

One of the first large-scale efforts in forest management in the country was carried out in stands of red pine—this under the Morris Act of 1902.[8] About 190,000 acres supporting virgin timber, the major part of which was red pine within what is now the Chippewa National Forest, were purchased from the Indians. The red pine and white pine timber was cut and utilized for sawlogs through commercial sale with, however, the stipulation that part of the stand be held as seed trees. Chapman (7) has written an historical account of the events leading to the passage of this act.

The act originally provided for leaving 5 percent of the total volume of the red pine and white pine stand over 10 inches diameter at breast height in scattered seed trees. Amendment in 1908 increased the seed-tree volume to 10 percent. In the marking of the stand to be left, care was used to select the younger and healthier trees whenever possible, with emphasis on the size and vigor of crown.[9]

In order to ascertain the number of seed trees per acre in the red pine type and other information about the stands left, the old scaling and marking records were consulted. Data were summarized for 3 sample areas in the 5-percent marking aggregating 919 acres and for 4 areas in the 10-percent marking totaling 1,463 acres. This analysis indicated an average of 1 seed tree per acre in the 5-percent marking and 6 per acre in the 10-percent marking. Red pine seed trees ranged in diameter from 11 to 32 inches and white pine up to 40 inches. The average red pine seed tree was 15 inches in diameter and the average white pine 18 inches. The trees left were from 80 to 90 feet tall on

[8] White pine also came under the provisions of this act, but is not covered in this report.

[9] Communication from H. H. Richmond (formerly forest assistant, Chippewa National Forest), who participated in the marking from 1912 to 1918.

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the average with an occasional taller tree. Under the 10-percent method, 1,334 board feet, Scribner, per acre were left, about 90 percent of it red pine. Seed trees ranged in age from 150 to 250 years and in some cases were older (fig. 7). Notations on the record sheets made at the time of marking indicated the presence of advance reproduction of red pine in many places under the old stand.

FIGURE 7.—Abundant red pine reproduction a few years following a seed-tree cutting. Most of the seedlings were present before logging. Cut Foot Sioux District, Chippewa National Forest, Minn.

That windfall among seed trees was prevalent soon after cutting was disclosed by the examination of the old scale records. Windfall losses were salvaged on 19 of 61 sections where red pine predominated. On one section the loss was 66 percent, but the average was only 18 percent.

In addition to the seed trees, all red pine and white pine trees under 10 inches diameter at breast height, whether in the stand being cut or in adjacent stands, were required to be left, together with all trees of other species regardless of size.[10] A considerable proportion of the latter was jack pine. Cutting was begun in 1904 and was completed in 1923.

EARLY APPRAISALS OF RESULTS

Various appraisals of the results of the seed-tree cuttings under the Morris Act have been made. In reviewing these reports, it should be kept in mind that red pine produces good seed crops only every 3 to 5 years and sometimes as infrequently as 7 years. Good seed production occurred in 1904, 1910, 1914, 1917, 1920, 1924, 1927, 1930,

[10] The Morris Act also reserved from cutting 10 sections of old-growth red and white pine timber.

1937, 1943, and 1944, or on an average of once every 4 years with some partial crops in between.

Fire protection was not especially effective during the earlier years of these operations. Red pine reproduction suffered accordingly. Under the terms of the logging contracts, slash was required to be piled and burned. Much good advance reproduction that in many places covered the ground under mature stands was lost by careless slash burning and lack of an effective fire protection organization during the earlier years [11] (fig. 8). Still, many areas escaped burning. The following extracts of written accounts apply where fire did not follow logging to upset results. They express considerable difference of opinion as to the success of the seed-tree cuttings.

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FIGURE 8.—Seed-tree cutting in red pine. The photograph, taken in 1939, shows the area 13 years after a surface fire. The area has been taken over by sod and brush and there is no reproduction. Pike Bay Experimental Forest, Cass County, Minn.

The first report noted, one made in 1906 (*3*) soon after the cuttings were started, indicated that only 15 percent of the seed trees had blown down despite two severe windstorms the previous year.

In 1912, Zon (*39*) reported on an inspection of some of the 1904 cuttings where 5 percent of the volume had been reserved in seed trees. He concluded that conditions favorable for reproduction of red pine consist of a good seed year at the time of cutting and ground reasonably free from weeds. Where good reproduction had been obtained, it had been due to accidental combination of these favorable circumstances rather than to the method.

Benedict [12] said in 1912 that 90 percent of the reproduction under seed-tree cuttings had originated prior to logging.

[11] Information obtained in a personal interview with Joseph E. Donery, formerly Logging Engineer, U. S. Forest Service, who participated in much of the early timber marking.

[12] Benedict, J. St. J. Typewritten report, Chippewa National Forest. 1912.

Conzet[13] in 1913, on the basis of a very small sample of the 5-percent seed-tree cuttings, reported 41 percent loss of seed trees from causes other than wind. A study of seedling age indicated that 76 percent of the seedlings found had been present when cutting took place. He observed that if the forest is cut 1 or 2 years after a good seed year, with at least moderate rainfall, the establishment of the seedlings will be most certain; that where there is dense brush or dense grass or very open places, there is no reproduction; and that over 60 percent of the seedlings were within 50 feet of the seed trees. He concluded that in 6 years insufficient seedlings had become established to produce a good stand.

Reporting in 1914 on the results of these seed-tree cuttings, Woolsey and Chapman (*38*) wrote:

> Taken as a whole, the natural reproduction is not a success, because not enough seed fell immediately after logging, when the bared soil was in the best condition to receive it. What young growth there is has sprung up as a result of the chance combination of a good seed year with a suitable condition of the soil. Where conditions have been favorable, however, the results are unexpectedly good.

One-fourth of the seed trees are said to have blown down.

Richmond[14] in 1916 stated that such reproduction as was present was almost entirely advance growth. Lack of reproduction close to seed trees on exposed mineral soil was attributed to failure of newly germinated seedlings to survive hot, dry summer weather. This explanation is entirely plausible since it has been demonstrated that soil surface temperatures above 122° F., if they continue for a period of 2 hours, endanger young conifer seedlings (*34*). Such temperatures are likely to occur on exposed sites during hot summers. Richmond also found that where a light fire happened to run over the ground preceding a good seed year, regeneration was abundant.

In 1922, Petheram[15] observed that the stocking was very variable—everything from overstocking to none at all. His counts showed that one-fourth and in some cases up to one-half of the seedlings came in after logging from seed scattered by seed trees. Seed trees were ineffective where heavy sod prevented the seed from reaching the ground. Jack pine reproduced abundantly in some places in the red pine type. Response in diameter growth rate of seed trees was beginning to become evident. Petheram concluded that seed-tree cuttings had been fairly successful generally in reproducing the area but that too much money was tied up in the timber left.

The following year (1923), Bates[16] sampled 7 separate areas by laying out transects 300 feet long and 10 to 16 feet wide. The average stocking for the areas studied was found to be 2,111 seedlings per acre, 72 percent of which was red pine, 25 percent white pine, and 3 percent jack pine.

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[13] Conzet, G. M. A qualitative and quantitative study of the seed production and reproduction of Norway pine. 1913. [Unpublished thesis, University of Minnesota.]

[14] Richmond, H. H. Growth and yield of Norway pine. Minnesota [Chippewa] National Forest, Cass Lake, Minn. 1916. [Typewritten report.]

[15] Petheram, H. D. Typewritten report on examination of reproduction on Minnesota [Chippewa] National Forest, Cass Lake, Minn. 1922.

[16] Bates, C. G. Typewritten report. U. S. Forest Service, 1923.

An Examination 20 Years Later

As time went on, many of the local foresters tended to forget the fail spots as they became filled in with jack pine and the general impression "got around" that the seed-tree method for managing red pine was highly successful. The whole subject, however, was still debated to such an extent that another checkup was made of unburned seed-tree areas during 1944.

In this investigation time did not permit a systematic survey that could be relied upon for an accurate picture of stocking over the whole red pine area, but several questions did receive careful attention. In particular this study aimed to determine: (1) What proportion of the reproduction existed as advance growth prior to logging and the proportionate representation in the reproduction of the three species of pines, (2) the effective seeding range of seed trees, and (3) growth both of seed trees and the residual stand of smaller trees left at the time of logging.

REPRODUCTION

In order to ascertain the proportion of reproduction originating before cutting and that which came in afterwards and the representation by species, four separate well-stocked areas were studied. Each area was of considerable size and none less than 80 acres in extent. Three of the areas were abundantly supplied with red pine seed trees; one had none. Age determinations were carefully made of the reproduction and second growth by means of ring counts on 249 trees.

Area 1 (table 1) was cut in 1917–18. Although some seed trees may have been left at the time of logging, none was present in 1944. Of the milacre quadrats examined, 75 percent are now stocked with red pine, 45 percent with white pine, and 85 percent of all have at least one seedling of one or the other of these species. Despite the fact that 1917 was a heavy seed year, all of the red pine and 93 percent of the white pine reproduction antedated the cutting.

Table 1.—*Natural reproduction of red pine per acre before and after seed-tree cuttings, Cass and Itasca Counties, Minn.*

Area	Seed trees [1]	Total reproduction	Reproduction by species			Time of establishment of red pine		Basis, milacre quadrats
			Red pine	White pine	Jack pine	Before cutting	After cutting	
	Number	*Number*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Number*
1	0	2,150	67	33	----------	100	0	20
2 [2]	30	2,350	64	36	----------	74	26	20
3	12	1,851	29	7	64	53	47	60
4	16	3,317	52	48	----------	35	65	60
Average	14.5	2,417	54	34	12	[3] 62	38	----------

[1] Red pine trees over 10 inches diameter at breast height in 1944. Many of these were under 10 inches diameter at breast height at the time of logging. No white pine or jack pine seed trees were left on the sample areas studied although an occasional one of the former was left on adjacent areas.

[2] This represents more nearly a shelterwood cutting than a seed-tree cutting.

[3] White pine was 57 percent advance reproduction and jack pine 21 percent.

Area 2 (table 1) was cut about the same time as area 1, but differed in that it had ample seed trees, many of which were under 10 inches diameter at breast height at the time of logging. These trees have been responsible for considerable seeding-in subsequent to logging. Eighty percent of the quadrats examined were stocked with red pine and 60 percent with white pine. Taking both species together, there is a 95-percent stocking. Most of the post-logging red pine reproduction came in during the first 10 years after cutting. Although a little

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FIGURE 9.—Seed-tree cutting in red pine as it appeared about 20 years after logging. Three-fourths of the reproduction was present as advance growth before cutting took place. Most of the rest became established immediately following logging. Bena District, Chippewa National Forest, Minn.

seeding is still taking place, it is doubtful whether these new seedlings will ever come through to form a part of the stand. The advance growth will likely suppress them. Figure 9 shows a nearby stand where the seed trees were less abundant.

On area 3 (table 1) which was logged in 1922–23 when the stand was 130 years old, many trees under 10 inches diameter at breast height were left. A second partial cutting was made in 1939. Twenty-three percent of the reproduction quadrats are at present stocked with red pine, 10 percent with white pine, and 58 percent with jack pine. All told, there is a stocking of 70 percent.

An analysis shows that 53 percent of the red pine reproduction was advance growth in 1923, that 21 percent came in during the 18 years between the two cutting operations, and that 26 percent became established at the time of or following the second cutting. Stirring up of the ground by the second logging evidently had a very beneficial effect. The proportion of jack pine reproduction is large on area 3. Figure 10 illustrates this type of stand on another part of the Chip-

pewa National Forest. Ring counts showed that 21 percent of the reproduction was present at the time of logging, that 32 percent came in during the first 10 years after logging, and 47 percent more recently.

This recent reproduction of jack pine seems to have resulted from the seed produced by trees which were present as advance reproduction at the time of the first cutting. This is indicative of what has happened in many places. Jack pine thus has helped materially to fill up the gaps and form good stands.

FIGURE 10.—Seed-tree cutting in red pine type that has reproduced mostly to jack pine. Bena District, Chippewa National Forest, Minn.

With its capacity to produce seed in large quantities at very early ages (10 years and younger) jack pine is much superior to red pine. Open-grown red pine may begin to produce a little seed at about 20 years (*38*) and there are records of production of viable seed in planted stands as young as 12 years (*25*). It is not until trees grown in dense stands are 80 years and older that they become heavy producers.

Area 4 (table 1), which was cut in 1923, is another case where the small size of the trees prevented heavy cutting. Not over 60 percent of the volume was removed. Like area 3, it received a second cut in 1939. Altogether 90 percent of the quadrats are now stocked. Fifty-one percent of the quadrats have red pine seedlings and 60 percent are stocked with white pine. In this instance, only 35 percent of the red pine was advance reproduction; 43 percent became established during the 15 years following logging; the rest seeded in later. This area, like area 2, approaches the shelterwood method because of the large number of trees left which, of course, explains the rather effective regeneration of the tract subsequent to logging.

In summarizing the effectiveness of the seed-tree method on the four sample areas, it is plain that advance reproduction of red pine

played a very important part in restocking the areas, since about two-thirds of the red pine reproduction present was there before cutting. No seed trees of white pine were left within the sample strip and only an occasional one in the general vicinity. Nonetheless white pine now comprises one-third of the total reproduction. Over half of this was advance reproduction. Since there were no seed trees of jack pine left on the study plots at the time of logging, it is concluded that the jack pine regeneration now present seeded-in from trees that were of reproduction size when cutting took place, but which have now become seed producers.

The data just presented are from areas well stocked with reproduction. Various seed-tree cuttings where reproduction failed to become established following logging were also observed but no specific counts made. Aside from fire, the most common cause of failure seemed to be the rapid occupation of the site by brush or sod as soon as it was exposed.

EFFECTIVE RANGE OF SEED TREES

In order to determine the effective range of seed trees, the distance from each plot to the nearest seed tree was recorded for the 160 milacre quadrats summarized in table 1. In addition, 4 strips were run at right angles from each other from each of 18 seed trees in the various areas where the trees were standing alone. The reproduction known to have become established after logging was tallied separately by quadrats according to the distance from the seed tree. Seedlings

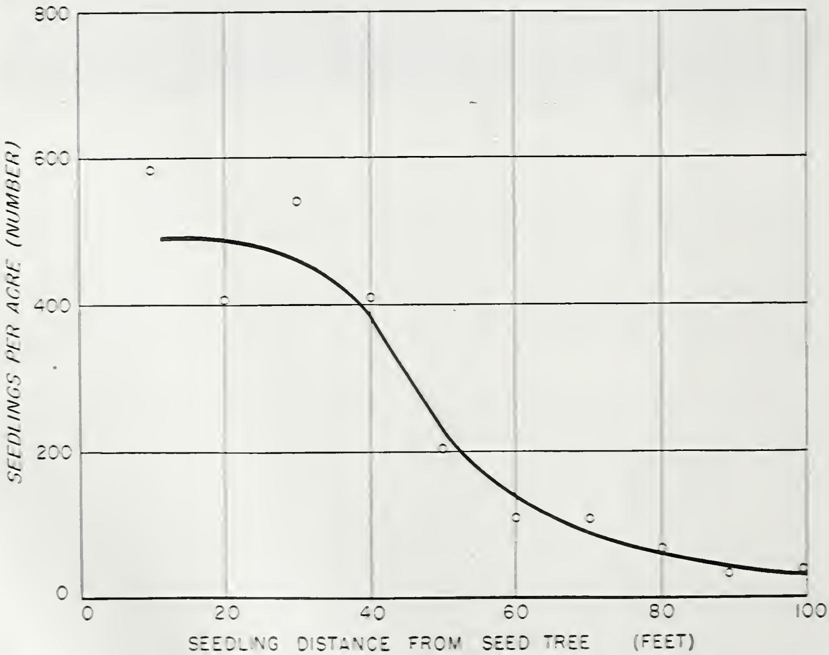

FIGURE 11.—Relation of establishment of seedlings per acre on milacre quadrats after cutting to distance from seed tree. Basis—1,195 quadrats in Cass and Itasca Counties, Minn.

on 1,035 quadrats were recorded in this manner making a total of 1,195 quadrats in all. The data from both sets of records, which did not consider advance reproduction but only that originating from seed trees after logging, are combined in figure 11.

As seen from this chart, the effectiveness of the seed trees decreases rapidly at a distance over 40 feet—a very close agreement with a previous study by Conzet.[17] Seeding does, of course, occur at much greater distances, but 80 percent of the reproduction found in these examinations took place within 40 feet of the seed trees. Even within this distance the stocking, as a result of seed trees alone, averaged only 485 seedlings per acre. Considering 1,200 seedlings per acre as satisfactory stocking, then the stocking at 30 feet originating from the seed trees is 45 percent satisfactory.

GROWTH OF SEED TREES

In examining several of the areas cut under the Morris Act, it was apparent that the residual trees—both seed trees and the small ones under 10 inches diameter at breast height—had developed a great deal since logging. In order to acquire further data on the present volume and to determine the growth response, a study was made in 1945 of a sample tract on the Cutfoot Experimental Forest which had been cut over under the seed-tree method in 1915 where 10 percent of the volume had been left. Trees over 10 inches diameter at breast height were tallied by diameter and thrift classes on more than 2 miles of 2-chain-wide transect or a sample of 33.4 acres. Increment borings were made in 122 trees the ages of which ranged from 100 to 250 years. The trees in this study are a little younger than the average seed tree left in Morris Act cuttings.

The study disclosed that the trees over 10 inches diameter at breast height now number 5.1 per acre and have a gross volume of 1,209 board feet.[18] Incidentally, 90 percent of the volume and 72 percent of the number of trees now present were over 10 inches diameter at breast height at the time logging was completed. Projecting the growth backward, there were 3.6 trees over 10 inches diameter at breast height or 532 board feet per acre present in 1915. In other words, there has been an increase in volume of 128 percent during the 30-year period, or 4.3 percent annually. This, however, includes the ingrowth of trees under 10 inches diameter at breast height at the time of logging. The old seed trees themselves that have survived since logging have grown at the rate of 3.5 percent annually. No attempt was made to estimate loss through windfall or other cause on this study area. The growth figures are merely those for the surviving trees. A check of old records, however, for the section on which the borings were made showed that 30 percent of the seed trees blew down or were broken off soon after cutting and were salvaged immediately. The initial losses from wind were evidently much greater than those in later years after the seed trees became stabilized.

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[17] See footnote 13, p. 10.

[18] The board-foot volumes given here and those subsequently used in this publication are for the Scribner Decimal C rule, gross scale, except where otherwise noted. Red pine is very sound and rarely does cull exceed 5 to 10 percent. In second growth, where trees are utilized closely in short lengths, it is usually less.

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TABLE 2.—*Diameter growth of red pine seed trees before and after cutting, by 10-year periods for 1914 diameter at breast height groups*

Period	Diameter at breast height group in 1914				Average
	5 to 9 inches	10 to 14 inches	15 to 19 inches	20 inches and up	
Before cutting:	*Inches*	*Inches*	*Inches*	*Inches*	*Inches*
1885–94	0.76	1.19	1.16	1.08	1.05
1895–1904	.71	1.08	1.19	1.00	.98
1905–14	.63	.81	.76	.66	.74
After cutting:					
1915–24	1.40	1.17	.95	.84	1.18
1925–34	1.33	1.31	1.22	1.15	1.29
1934–44	1.15	1.04	.90	.77	1.03
	Number	*Number*	*Number*	*Number*	
Basis (trees)	38	53	26	5	

Periodic diameter growth by 5-inch diameter groups for the trees now remaining is shown in table 2 and figure 12. Before the tract was logged, the smaller trees had been making the poorest growth. Now they are doing the best. The larger trees have maintained a fairly even diameter growth but in the last decade have fallen off slightly. In evaluating these data it should be kept in mind that the larger trees are putting on considerably greater volume increment despite the lessened diameter growth.

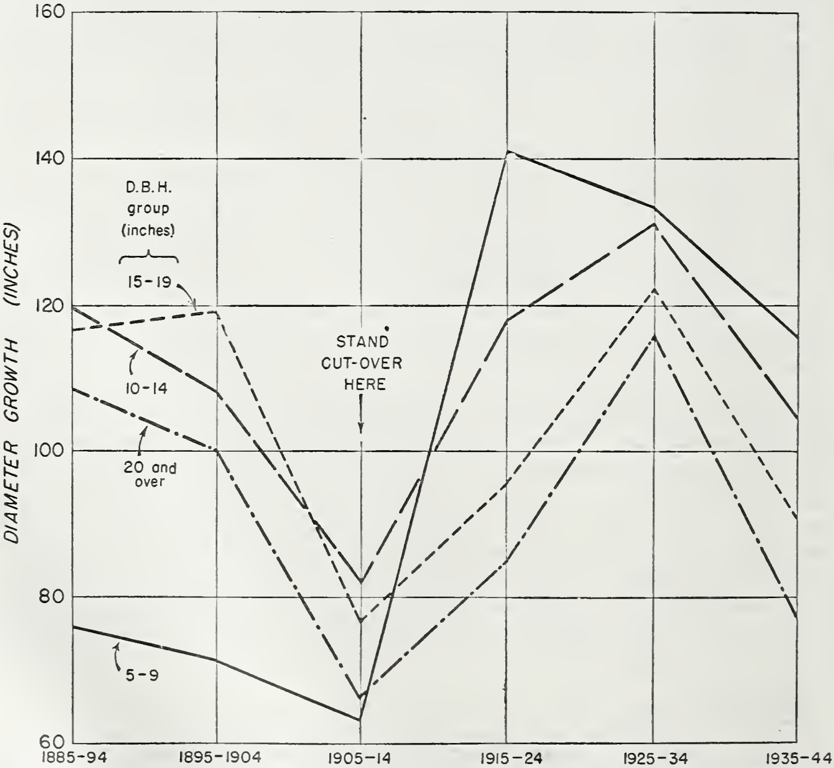

FIGURE 12.—Diameter growth of red pine seed trees by 10-year periods and diameter at breast height groups. Diameter at breast height groups: 5–9 inches, 10–14 inches, 15–19 inches, 20 inches and larger.

There was a sharp response in diameter growth after cutting (fig. 12) amounting to nearly a 60-percent increase on the average during the first decade. It will be noted that the growth had slowed down appreciably during the decade prior to cutting. The drought period of 1910 may have had some effect but the more likely cause was the closing-in of the stand. The recent slowing down may be due to the more advanced age of the trees, since crowding is not evident in very many cases. It is interesting to note how well the growth has been maintained on these seed trees which by no standard would be considered young.

As the trees were bored they were roughly classified into three vigor classes, largely on the basis of the appearance of the crowns. As shown in table 3, there is a clear-cut relationship between vigor and diameter growth. Hence it should be relatively easy to select the trees which need early removal.

The growth of these seed trees has been excellent, not only in volume but in quality. Where there was a fair representation of smaller trees left, there is now an appreciable volume of timber present. The quality is high since the trees had originally grown in a fairly dense stand and were well pruned. The seed trees, taken together with the advance growth of jack pine, which has grown more rapidly, now make up another forest. Many of the red pine seed trees are ready for harvest. They help in "sweetening" the cut for the logger, thus making possible the sale of the products of improvement cuttings in young or poorly formed jack pine. The utilization of the seed trees when considered along with the large volume of jack pine aid in sustained yield management on the Chippewa National Forest by helping to bridge the gap between the time when the old growth was cut out and the time when second growth will come into heavy production.

TABLE 3.—*Diameter growth of seed trees, before and after cutting, for vigor classes by 10-year periods*

Period	Vigor class [1]		
	Good	Medium	Poor
Before cutting:	*Inches*	*Inches*	*Inches*
1885–94	1.17	0.98	0.82
1895–1904	1.09	.96	.70
1905–14	.82	.72	.56
After cutting:			
1915–24	1.35	1.10	.90
1925–34	1.52	1.11	.89
1935–44	1.15	.93	.74
	Number	*Number*	*Number*
Basis (trees)	53	51	8

[1] As of 1945. Vigor was estimated mainly on the basis of size and density of crown.

Reduction of Fire Hazard Through Slash Disposal

During the progress of the seed-tree cuttings under the Morris Act, slash was burned in order to reduce fire hazard. Several methods were tried (*20*). At first slash was piled and burned in the spring following logging. As the results were not entirely satisfactory, piling was undertaken at the time of logging. Although some repiling was necessary before burning in the spring, this method was an improve-

ment over the first. In thick timber, both of these practices resulted in so many piles that the area burned over amounted to one-tenth to one-fifth of the total.

Following this came the system of progressive burning; that is, completely disposing of the slash by burning on the snow as fast as the trees are limbed. Very few brush fires are necessary if cutters carefully plan their work so as to fell as many trees as possible toward one fire. Such disposal caused the least damage to residual trees and cheapened skidding by freeing the ground of impeding debris. The main drawback of progressive burning is that it is unsafe to follow in summer logging.

General Effectiveness of the Seed-Tree Method

Considering all of the evidence available on seed-tree cuttings in red pine—published data, unpublished reports, and recent observations on the results under the Morris Act—certain conclusions may be drawn as follows:

1. On the average, nearly two-thirds of the reproduction on seed-tree areas became established before cutting. Thus the seed trees had less effect than advance reproduction on restocking areas with red pine.
2. When good seed years coincide with time of logging, reproduction is usually successful.
3. The effective seeding range of seed trees is very short, decreasing rapidly at distances greater than 40 feet.
4. The most common cause of failure of reproduction, aside from fire, is the presence of a heavy stand of brush or a thick sod of grass before cutting, or the rapid invasion of shrubs and grass immediately after cutting. Many times, however, hot, dry weather is a contributing factor.
5. The general good stocking of many areas is due in no small measure to the aggressive seeding in of jack pine. This is especially true where fires have overrun the areas.
6. Seed trees are subject to heavy windthrow and other losses but these can usually be salvaged because of the high quality of the timber and its ready accessibility.
7. Considering their advanced age, seed trees left in old-growth cuttings have made very satisfactory growth. The value of these trees for the wood they contain has been high.
8. The seed-tree method as applied under the Morris Act has many shortcomings as a method of forest management and was only a compromise measure. The results, however, have fully justified its adoption. It was a forward step and has paved the way for more intensive forestry as improved markets for timber have developed.

MANAGEMENT UNDER A TWO-CUT SYSTEM

The inadequacies of the seed-tree method as a means of managing red pine have long been recognized and some form of the shelterwood system of cutting had been frequently advocated (*10, 26, 39*).[19] [20] In the simplest adaptation of the shelterwood method the timber stand is

[19] See footnote 14, p. 10.
[20] See footnote 15, p. 10.

removed in two cuts spaced by a sufficient interval to permit regeneration of a new crop under the protection of a partial stand. A two-cut type of cutting, known locally as the "60–40 method," was in effect on the Chippewa National Forest for a number of years after seed-tree cuttings were concluded but before better markets made intermediate cuttings feasible. This policy called for removal of about 60 percent of the merchantable volume in the first cut and the balance after reproduction had become established.

Effect on Reproduction

ADEQUACY OF SEED SUPPLY

Any stand handled under a shelterwood form of cutting has an obvious advantage over one cut under the seed-tree method in its capacity to supply seed. Obvious, too, is the protection from the hot rays of the sun afforded tender seedlings by a partial overhead cover. Seed-tree cuttings may leave 5 or 6 seed trees per acre, but the number will vary from less than 1 tree per acre to as many as 10 or more. It all depends on the intensity with which the method is applied. In contrast, the two-cut shelterwood method would leave from 40 to 60 percent of the stand over 10 inches in diameter (fig. 13). In a number of observed examples where the method had been tried, from 30 to 140 red pines per acre were left, or over 10 times as many as would ordinarily be provided under a seed-tree method. An adequate seed supply is therefore assured if the crowns of the remaining trees are sufficiently developed to produce seed in quantity and the stand is held long enough to encompass one or more good seed years.

F-447543

FIGURE 13.—Red pine 110 years old cut over by the shelterwood method 20 years previously. A second light cutting just completed has removed a few additional trees.

CROWN DEVELOPMENT AND SEED PRODUCTION

That seed supply may not always be adequate was revealed in an attempt to reproduce a dense 75-year-old red pine-jack pine stand by leaving a partial stand composed of the best red pines. The cutting area was 2.8 acres. The stand was cut in 1937, a good seed year. Prior to cone ripening, the ground was scarified with a disk. Logging took place in November following the seed fall. All of the jack pine and some of the red pine or a total of 10,750 board feet per acre was removed, but 30 of the largest red pines per acre, averaging 13.7 inches diameter at breast height were left to provide seed. In an effort to prevent jack pine reproduction from coming in, all the jack pine slash was piled and burned.

The number of seedlings present in 1938 and in 1944 is given in table 4. Altogether the area is now satisfactorily reproduced with mixed pine. But the proportion of red pine originating before 1944 was disappointingly low. Few red pine appeared immediately after logging despite a good seed crop at the time, the preparation of a seedbed by scarification of the ground, and favorable weather the first 2 years following cutting. This failure may be explained partially by the observation that trees of this age growing in well-stocked stands do not produce great quantities of seed and the 1937 seeding here was insufficient to obtain the desired results. If the stand left had been greater than 30 trees per acre, the results might have been better. The jack pine apparently originated from seed dispersed from cones which were accidentally knocked off the branches while being handled inasmuch as the slash was piled and burned and no jack pine seed trees were left. The area is now becoming rather brushy and it is doubtful whether very many of the 1944 seedlings will pull through. Of the seedlings originating before 1944, practically all of the red pine and jack pine are survivors of the 1938 reproduction, whereas the white pine has continued to come in.

Probably the most significant thing learned in the experiment, and a point not previously appreciated, was the inability of 30 14-inch red pines grown in a well-stocked stand to provide enough seed promptly to restock the area. However, 6 years later, having room to expand their crowns, these same 30 trees produced an abundant seed crop which resulted in a good stand of seedlings, although by that time it was too late because brush had then encroached upon the area.

TABLE 4.—*Seedlings per acre in 1938 and 1944 following a heavy shelterwood cutting in 1937 in a 75-year-old mixed stand of red pine and jack pine on scarified soil*

Species	1938	1944 [1]		
		Old	New	Total
	Number	*Number*	*Number*	*Number*
Red pine	633	605	1,850	2,455
Jack pine	1,111	1,090		1,090
White pine	50	385		385
Total	1,794	2,080	1,850	[2] 3,930

[1] "Old" represents seedlings originating prior to 1944 and "new" those which germinated that year as a result of the 1943 seed crop.

[2] Based on a count of 180 milacre quadrats, Cutfoot Experimental Forest, Itasca County, Minn.

RELATION OF BRUSH GROWTH TO OVERHEAD SHADE

Rapid brush invasion has been one of the most important causes of failure of red pine reproduction in the general exploitation of the virgin forest by clear cutting and under the seed-tree cuttings previously described. Of the various species of underbrush the worst offenders are beaked filbert (*Corylus cornuta*) and American filbert (*C. americana*) both commonly known in Minnesota as hazel brush. Other troublesome species are American green alder (*Alnus crispa*), prairie willow (*Salix humilis*), dwarf bushhoneysuckle (*Diervilla lonicera*), Canada blueberry (*Vaccinium canadense*), and lowbush blueberry (*V. angustifolium*).

A cutting method that leaves part of the overhead canopy will prove helpful in holding down the noxious growth of brush. On sandy soil of intermediate quality where red pine is typically at home, the leaving of half the stand should prove sufficiently effective in this respect to bring through the reproduction, either advance growth present at the time of cutting or that which seeds in later.

The first two examples given in table 5 illustrate the successful application of a two-cut method. These two stands are on typical red pine soils of rather low site quality and are not very brushy, but might have become so under clear cutting. They are fairly comparable with those where the seed-tree data previously presented were collected. Both stands, area 2 especially, have closed in markedly, with the result that very little brush has developed. This is due in no small measure to the growth of trees that were under 10 inches diameter at breast height at the time of logging. Doubtless some reproduction in the more shaded places has died. The second or removal cut is now needed to bring the reproduction through.

TABLE 5.—*Reproduction per acre in 1944 following shelterwood cuttings in red pine in Beltrami and Itasca Counties, Minn.*

Area [1]	Date cut	Age when cut	Present height dominant stand	Estimated volume per acre before cutting [2]	Volume cut	Red pine seed trees left per acre [3]	Basal area, 1944	Reproduction per acre [4]			
								Red pine	White pine	Jack pine	Total
		Years	*Feet*	*Board feet*	*Percent*	*Number*	*Square feet*	*Number*	*Number*	*Number*	*Number*
1	1924	110	75	17,715	40	80	74	2,450	100	100	2,650
2	1926	90	75	16,862	26	90	137	2,300	850	0	3,150
3	1934	70	75	17,377	59	52	86	615	365	215	[5] 1,195
4	1936	125	80	22,375	60	80	98	100	2,605	0	2,705

[1] Areas 1, 2, and 4 are in Beltrami County; area 3 (plot 108) is in Itasca County.
[2] Board feet, Scribner, for trees 7.6 inches diameter at breast height and larger to a 6-inch top diameter inside bark.
[3] Over 10 inches diameter at breast height at time of logging. No white pine or jack pine seed trees were present.
[4] Based on 20 milacre quadrats each in areas 1, 2, and 4, and 60 in area 3.
[5] The count and measurements on this cutting were made in 1946. The seed trees were those present in 1934 after cutting.

Area 3 (table 5) is an example of the shelterwood method working out quite satisfactorily in a somewhat younger stand. At the time of cutting, the stand was 70 years old on a site classified as high-medium. It was well stocked and not brushy. Although a 70-year

stand is not a heavy seed producer ordinarily, some seeding was already taking place here as there were 115 red pine, 290 white pine, and 35 jack pine seedlings per acre present in 1934. Thirty-eight percent of the stand volume was removed at that time and an additional 21 percent (mostly jack pine) in 1940 to salvage sleet-broken trees.

In 1946, the reproduction had increased so that there were then 615 red pines, 365 white pines, and 215 jack pines, or a total of 1,195 seedlings per acre (fig. 14). Two-thirds of the quadrats were stocked.

F-442829

FIGURE 14.—Shelterwood cutting in red pine. This stand, now 82 years old, has had two cuttings. The first, made 12 years ago, removed 38 percent of the volume, the second made 6 years before the photograph was taken, removed 21 percent. The reproduction visible resulted mostly from the first cutting. Cutfoot Experimental Forest, 1946.

As the count was made when there were 12 inches of snow on the ground, the reproduction is all over 1 foot high, most of it over 3 feet. The red pine reproduction is almost entirely the result of the 1934 cutting. No doubt some smaller seedlings are also present which originated following the 1940 cut.

Area 4, as indicated in table 5 and figure 15, shows what may happen when the soil is heavier. Here a considerable growth of brush was present before cutting, although in spots there was good advance reproduction of white pine. This evidently seeded in from trees that were removed in the logging operation. Before cutting the stand was too dense to permit establishment of red pine seedlings. Since logging very little red pine reproduction has resulted, mainly because of the aggressiveness of the brush. The advance reproduction of white pine which was present at the time of logging, ranging in density from 1,600 to 4,000 per acre is, in fact, in grave danger of being choked out by the brush unless given release treatment. This

is especially true of the more heavily cut portions of the area. Had the area been cut lighter, it is probable that the white pine reproduction could have been brought through with less difficulty.

In anticipation that the brush would prevent restocking with red pine, the more open areas where white pine reproduction was sparse were planted to red pine following cutting. However, because of lack of release cutting, the planted trees are now fighting a losing battle with the fast-growing brush. The presence of brush undergrowth before cutting decidedly lessens the chances of success in establishing reproduction under the two-cut system.

F-442828

FIGURE 15.—Shelterwood cutting in 125-year-old red pine 10 years after logging. Brush now occupying the ground has prevented establishment of reproduction. Beltrami County, Minn.

LOGGING DAMAGE TO REPRODUCTION

Loss of reproduction due to logging under a two-cut method may be heavy. Light is thrown on this question by the results of an experiment in which the timber was removed, not in two but in three operations. Before cutting, the stand, then 100 years old, supported a volume of 24,000 board feet per acre, mostly red pine. The ground underneath this dense stand of red pine was stocked with some 4,000 white pine seedlings per acre 2 to 4 inches tall (table 6). One-fourth of the timber volume was removed in February 1926, two-thirds of the remainder in March 1931, and the balance in March 1936.

The count of seedlings in 1927 after the first cut showed no loss. The seedlings were, of course, very small at the time and the snow evidently furnished protection. In 1931, as the result of a heavy cut, logging late in the winter when there was less snow, and the presence of large seedlings more susceptible of injury than small ones, there was a sharp drop in the number of seedlings surviving. The further

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losses that followed the 1936 operation were probably due mainly to logging damage to the large and more easily broken seedlings, although the drought of that year may have played a part. Despite losses, there are now more than 1,000 saplings per acre (fig. 16).

TABLE 6.—*Number of seedlings per acre and average height by species, Cass County, Minn.*[1]

Year	White pine		Red pine		Jack pine		Total seedlings per acre
	Seedlings per acre	Average height	Seedlings per acre	Average height	Seedlings per acre	Average height	
	Number	*Feet*	*Number*	*Feet*	*Number*	*Feet*	*Number*
1923	4,056	0.3	436	0.3	354	0.6	4,846
1926	3,988	.4	436	.4	381	.8	4,805
1927	4,002		422		340		4,764
1930	4,465	.7	558	.5	422	1.5	5,445
1931	1,729		286		150		2,165
1944	789	8.6	177	6.4	122	17.4	1,088

[1] Plot 1, Bena Cutting Experiment. Partial cuttings in 1926 and 1931, clear-cut in 1936.

Summer logging at a time when seedlings are more flexible than under freezing conditions is less injurious to reproduction than winter logging without good snow covering. It may be concluded that unless the operation is carried on while the seedlings are still small and the work is done at a time when a protective mantle of snow is on the ground, or extreme care is exercised in removal of the timber, considerable loss of reproduction will occur under a two-cut method. Tractor logging especially may be very damaging. If a tractor is used, the skid trails must be restricted to the fewest possible and should be located so as to avoid patches of advance reproduction.

F-447544

FIGURE 16.—Reproduction of mixed pine 10 years after shelterwood removal cut in red pine near Bena, Minn., Chippewa National Forest.

Slash created by logging under a two-cut method may be so abundant as to smother reproduction. It also represents a fire hazard so that some disposal may be necessary. If logging is done in winter, the progressive method of slash disposal used so effectively in seed-tree cuttings, previously described, is recommended. Otherwise, piling at least part of the slash during logging and burning after snowfall is the best alternative, although this method almost invariably results in some damage to the residual stand.

GROWTH OF REPRODUCTION UNDER A PARTIAL STAND

The density of the overhead canopy remaining after the first cut under a two-cut method of management is a decided factor in holding down growth of reproduction. The progressive development of reproduction for the three species of pine for the cutting described above may be seen in table 6. Annual height measurements are not available for red pine but are shown in figure 17 for white pine. This chart brings out clearly that removal of one-fourth of the stand (in

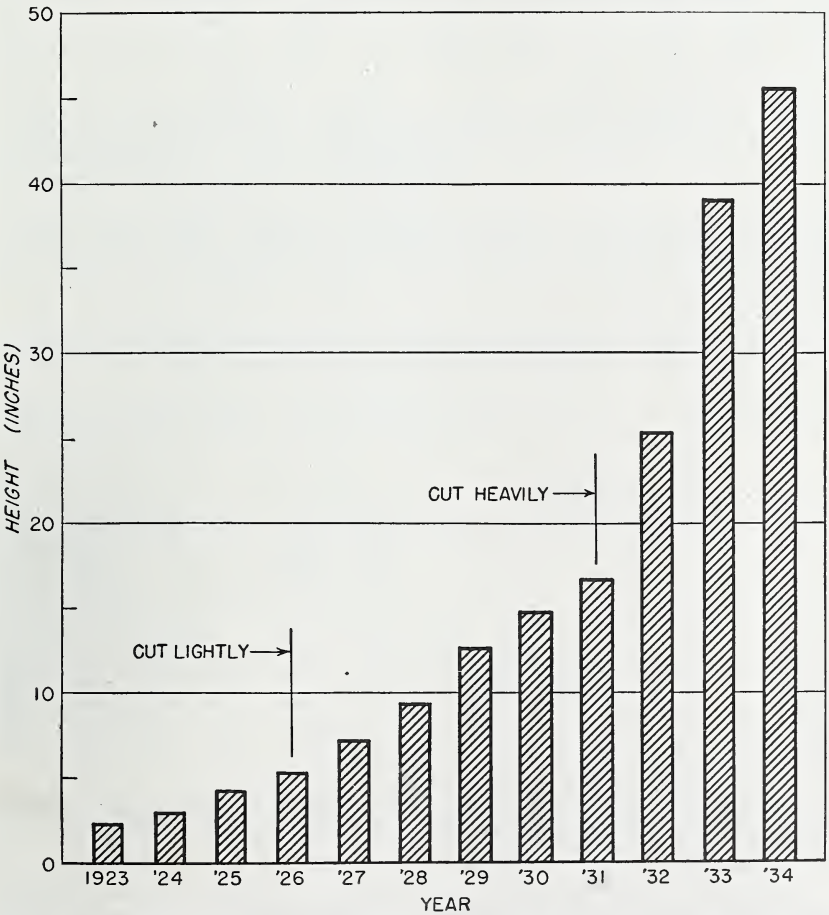

FIGURE 17.—Effect of cutting red pine overstory on growth rate of white pine reproduction.

1926) stimulated growth of reproduction very little. However, it shows the response to be immediate and striking when two-thirds of the remainder was cut (in 1931) and the basal area reduced to 43 square feet per acre.

The removal of the balance of the stand (in 1936) resulted in still further stimulation.[21] From the point of view of the best growth of red pine reproduction, the overstory should be removed as soon as the seedlings have developed enough to stand the shock of exposure and competition with the brush. This ordinarily would be in 5 to 8 years after establishment. For growth of the residual stand to amount to much, this period would have to be considerably longer.

Effect on Timber Growth

In appraising the advantages and disadvantages of the two-cut system, the effect on reproduction is only one of the considerations. The effect on growth of the timber left after the first cut has been applied is also important. The stand and growth statistics obtained following shelterwood cuttings in five different stands (four pure red pine and one mixed red pine-jack pine) in Beltrami and Itasca Counties are shown in tables 7 and 8. The information on the 70- and 75-year-old stands was based on repeat measurements of a permanent sample plot established in 1934. The data for the other cuttings were obtained in one examination in 1945. To get the latter, the stand after cutting was calculated by subtracting from the present stand the growth since cutting as shown by 192 increment cores distributed through the various diameter classes. The stand before cutting was then approximated by adding in the trees removed as shown by stumps.

Table 7.—*Stand per acre before and after shelterwood cuttings of red pine in Beltrami and Itasca Counties, Minn.*

Stand age [1] when cut (years)	Average height [2] dominant tree	Stand per acre before cutting: Trees	Stand per acre before cutting: Basal area	Stand per acre before cutting: Volume: Peeled volume including stump and top	Stand per acre before cutting: Volume: Gross log scale, Scribner rule	Stand per acre after cutting: Trees	Stand per acre after cutting: Basal area	Stand per acre after cutting: Volume: Peeled volume including stump and top	Stand per acre after cutting: Volume: Gross log scale, Scribner rule
	Feet	*Number*	*Square feet*	*Cubic feet*	*Board feet*	*Number*	*Square feet*	*Cubic feet*	*Board feet*
70	69	282	147	3, 950	17, 377	191	86	2, 655	10, 665
75	75	175	90	2, 784	11, 718	94	58	1, 755	8, 091
90	75	192	121	3, 735	16, 862	160	93	2, 837	12, 762
110	75	175	129	3, 898	17, 715	119	82	2, 424	10, 629
125	80	175	140	4, 627	22, 375	83	59	1, 904	8, 951
180	98	111	187	7, 726	41, 928	78	127	5, 171	28, 511

[1] The 70-year-old stand is a 2-acre permanent sample plot cut in 1934; the 75-year-old stand is the same stand cut again in 1940; the 90-, 110-, and 125-year-old stands are 1-acre temporary plots; the 180-year-old stand consists of three 0.4-acre plots. For age in 1947 add years since cutting given in table 8.
[2] At time of last measurement.

[21] It should be pointed out here that exposure of white pine of the size present on this plot is usually followed by a severe attack of white pine weevil (*Pissodes strobi*). That it did not occur here is probably due to the small size of the clear-cut area which was not much over an acre.

The reaction of the 90- and 110-year-old stands to such cutting (table 8) is about what can be expected under a two-cut system on average sites. The cutting could well have been slightly heavier, but on the whole, the results are satisfactory with an annual growth of 278 to 314 board feet per acre over an 18- to 20-year period.

TABLE 8.—*Growth per acre following shelterwood cutting in red pine in Beltrami and Itasca Counties, Minn.*

Stand age [1] when cut (years)	Years since cutting	Growth for period [2]: Total peeled volume including stump and top	Growth for period [2]: Gross log scale, Scribner rule	Growth per acre per year				Board-foot ingrowth [3]
		Cubic feet	*Board feet*	*Cubic feet*	*Percent*	*Board feet*	*Percent*	*Percent*
70	5	129	1,053	25.8	1.0	211	2.0	21.6
75	7	417	2,411	59.6	3.4	344	4.3	11.5
90	18	865	5,004	48.1	1.7	278	2.2	6.4
110	20	1,057	6,280	52.8	2.2	314	3.0	4.9
125	8	84	639	10.5	.6	80	.9	3.8
180	8	—78	—95	—9.8	—.2	—12	—.04	0

[1] The 70-year-old stand is a 2-acre permanent sample plot cut in 1934; the 75-year-old stand is the same stand cut again in 1940; the 90-, 110-, and 125-year-old stands are 1-acre temporary plots; the 180-year-old stand consists of three 0.4-acre plots. For age in 1947 add years since cutting.
[2] Deduction made for mortality but not for defect.
[3] Proportion of board-foot growth which was ingrowth.

The growth data given for the 125- and 180-year-old stands (table 8) illustrate what happens when the stands are too heavily stocked and the trees have lost their vigor before the cut is applied. In the case of the 125-year-old stand, despite the somewhat advanced age, there was a 33-percent acceleration in diameter growth in the 8-year period between cuttings; but even so, growth was poor. The rather slow volume increment here is largely explained by the thin crowns of the residual trees. The 180-year-old stand supported an exceptionally heavy volume and, as might be expected, was definitely too old and the crowns too poor to make satisfactory recovery.

The results of cutting in the 70-year-old stand which was a mixture of red and jack pine are particularly interesting as they point out possibilities of more intensive treatment (tables 7 and 8). This stand originally was well stocked and is on a high-medium site. Thirty-nine percent of the volume was removed in 1934 with the intention of cutting the balance after reproduction had become established and additional growth had been put on. The cutting took out 6,700 board feet per acre of which 5,700 was jack pine or about 72 percent of the jack pine then present. About 1,000 board feet of red pine per acre were removed. In 1939, 5 years after cutting, the plot was remeasured and the growth calculated at 211 board feet per acre per year for the period of which nearly 22 percent was ingrowth. This rather slow increment can be attributed (1) to a period of adjustment needed for the red pines to build up their crowns and root systems and (2) the presence of a considerable volume of jack pine which had almost ceased to grow.

In 1940, when the stand was 75 years old, a glaze seriously damaged the plot. Due to improved market conditions and to the large volume

of broken trees, it was now possible to make a salvage cut, a practice not considered feasible in the original cutting plan. This cut removed 90 percent of the remaining jack pine and 17 percent of the red pine aggregating 3,627 board feet per acre and left 8,091 board feet per acre (table 7). The good growth of 344 board feet per acre per year during the last 7 years (table 8) was an increase of 63 percent over the first period. This is evidently the result of the elimination of the slow-growing jack pine and the vigorous response of the red pines to opening up. Under the ordinary conception of the two-cut system the second cut as applied here would not have been possible. However, the benefits of such repeated cuts in salvaging damaged timber and in keeping the stand thrifty are self evident and point toward more intensive management as will be explained in sections to follow.

In summing up the results of experience with the two-cut shelterwood method, it is clear that it is a great improvement over the seed-tree method. In particular, the chances of obtaining satisfactory reproduction are better under the former because (1) the greater number of trees supply more seed, (2) newly germinated seedlings are better protected from the sun, and (3) more overhead shade tends to hold back the growth of brush and herbaceous plants.

The growth obtained under the two-cut method is better than under a seed-tree method because of the larger growing stock left to put on increment. The red pine trees left should, of course, be the most vigorous ones and any jack pine in mixture should be taken out in the first cut. There is somewhat less risk of loss through windfall under a two-cut method because the heavier stand affords some mutual protection to the remaining trees.

To be most successful the first cut should be made during a seed year preferably a short time before seed fall in order to gain the advantage of such ground scarification as will be afforded by summer logging. But it must be recognized that such timing of cutting is exceedingly difficult to accomplish in practice because of the infrequency and irregularity of seed years and the necessity for scheduling logging operations a long time in advance. The second or removal cut may destroy much reproduction and there is usually a long interval between cuts; hence, there is little opportunity to salvage scattered trees that succumb to pests or the elements. Retention of the overhead cover for too long a period will hold back the growth of reproduction and in extreme cases may result in loss of seedlings through suppression.

From the evidence presented, it is apparent that red pine on average sites can be reproduced by the two-cut form of the shelterwood method with a reasonable expectation of success. The first cut, which should remove about half the volume, may be applied almost any time between the ages of 70 and 140 years. Where good growth of the residual stand is a main consideration, the cut should not be made too late in this period. The final cut should be made 15 or 20 years later from the growth standpoint but at a much shorter interval to be of most advantage to reproduction.

The two-cut shelterwood method is not ideal but represents reasonably good forestry practice. It has particular application in less accessible localities where the market is limited chiefly to saw timber and where it is not economically feasible to sell the products of thinnings and intermediate cuttings.

INTENSIVE MANAGEMENT FOR HIGHEST PRODUCTION

The preceding sections, which describe (1) the first efforts to conserve red pine and (2) management on a rather extensive basis particularly of old-growth timber, show how fairly satisfactory results can be obtained by comparatively simple methods. Nevertheless, for maximum growth of high-value products more intensive practices are required. They are also more feasible silviculturally in second-growth stands which comprise the bulk of the timber now available for cutting.

Red pine lends itself well to forestry purposes. It responds well to good treatment. Of all species in northern Minnesota, it promises to pay back in growth and returns the most for the effort expended. It should, therefore, be handled by the best methods known. The balance of this report will be devoted to discussions of trials and experiments designed to get full production for various age classes and conditions and to recommendations based on the results of such treatment. The objective of these detailed prescriptions is to get throughout the rotation the greatest total yield of high-quality wood products for practicable utilization. However, before attempting to elaborate on practices for various classes of stands, it is necessary first to consider markets, accessibility, and some of the elements of species behavior as a basis for interpreting the findings and for making recommendations.

Relation of Utilization to Silviculture

Good markets, accessibility, and availability of workers experienced in logging are all prerequisites to intensive forest management. Fortunately, over most of northern Minnesota in areas where red pine is prevalent, there are excellent opportunities, prior to the final harvest, to sell a variety of forest products obtained from thinnings. The extensive iron mining industry, which utilizes large quantities of timber, contributes significantly to this market. For the products listed in table 9, red pine is always an acceptable species and for many items the preferred one. The volume tables given in the appendix will be found useful in estimating timber in terms of board feet or cords.

Markets for small-sized timber in such low-value products as pulpwood, mine lagging, and lath bolts permit close utilization in the woods and make it possible to thin overdense stands. Of these, pulpwood is by far the most important; the demand is strong, especially for out-of-state shipment, and the volume used annually is increasing. A market now developing for fence posts promises for the future another outlet for thinnings. Box bolts have a relatively steady sale but do not bring as high prices as mine timbers.

The mine-timber market, however, generally fluctuates to a greater extent. Small sawlogs can usually be disposed of at fairly good prices but mine timbers ordinarily bring higher returns. Consequently, when the mine-timber demand is active, small logs which have about the same specifications are sold to the mines for props rather than for sawlogs. Large sawlogs do not compete with mine timbers so price

depends mostly on quality of the timber and ease of logging. Year in and year out there is almost always a good market for quality sawlogs.

Red pine is now finding a ready market for use as power poles and indications are it will also be used extensively for telephone poles. The highest priced product for which red pine is suitable is piling, but strict specifications sharply limit the proportion of the stand that can qualify for this product. Table 9 shows the approximate values of the various products reduced to a cubic-foot basis. Piling clearly leads all products in value.

TABLE 9.—*Specifications and stumpage prices* [1] *of red pine for various forest products in northern Minnesota*

Product	Specifications	Unit of measure [2]	Approximate stumpage values	
			Per trade unit of measure	Per hundred cubic feet of solid wood
			Dollars	*Dollars*
Fuel wood	Usually material over 3-inch diameter	Cord	0– 0.25	0.20
Mine lagging	Round or split material to a 3½-inch top and 6 feet long.	6-foot cord (192 cubic feet).	0.50– 1.00	.65
Pulpwood:				
"Conversion" wood (unpeeled).	100-inch sticks to 3-inch top diameter inside bark.	Cord [3]	.75– 1.50	1.50
Standard (unpeeled)	100-inch sticks to 4-inch top diameter inside bark.	Cord [3]	1.00– 2.00	2.00
Fence posts	7 feet long, 2½- to 4-inch top	Each	.01– .02	2.00
Lath bolts	50 inches to 5-inch top diameter inside bark.	Cord	1.00– 2.50	2.50
Box bolts	8 feet long to 6-inch top diameter inside bark.	Thousand board feet.[4]	6.00–12.00	3.50
Cross-tie cuts	8 feet and 8 feet 6 inches long, 6 inches thick, with 7 inches or greater face.	Each	.15	3.75
Mine timbers	8 to 20 feet long and 7- to 16-inch top diameter inside bark.	Thousand board feet.	7.00–14.00	5.00
Telephone poles	16 feet long and up, 5-inch top	Linear foot	.01– .02	6.00
Sawlogs	8 to 16 feet long to 6-inch top diameter inside bark.	Thousand board feet.	8.00–16.00	6.00
Power poles	30 feet long and up, 5-inch top	Linear foot	.015– .03	7.50
Piling	25 feet long and up, 13-inch diameter at breast height, 8-inch top diameter inside bark straight.	Linear foot	.06– .12	12.50

[1] Prices given are those of 1942-45 which are generally about one-third higher than prewar prices; 1947 prices are considerably higher.
[2] Scribner Decimal C rule is most commonly used where timber is sold by the board foot.
[3] Usually sold on the basis of a 100-inch cord which contains about 4 percent more volume than the standard cord of 128 cubic feet.
[4] Box bolts are also sold by the cord.

Hand in hand with good markets as a necessary requirement for intensive forest management are accessibility of timber and qualified operators and labor to handle it. Most of the red pine tracts in northern Minnesota are found in accessible localities that are generally quite well supplied with secondary roads. Inasmuch as red pine occurs primarily on level to rolling sandy or gravelly lands, the problem of logging-road construction is relatively simple. The region is one of small loggers ("jobbers") and farmer-loggers who work only part time in the woods. Such family-sized operators living close to the woods frequently can log more cheaply than large companies because the former have lower overhead and supervision expenses, and often can work out from home without having to build logging camps.

Where logging can be carried out by such operators, the lower costs make it possible to remove light cuts and do a better all-around job

in the woods than where dependence must be placed on large operators. This is especially true once the workers are trained to do the kind of job required and return year after year to work in the same locality. These factors all react favorably toward intensive silvicultural practice and close utilization.

Factors Affecting Growth and Continued Production

In managing red pine for high production of good-quality marketable material, an understanding of some of the more basic factors of growth and ecology is essential.

GROWTH HABITS AND ROTATION

Red pine most commonly grows in even-aged stands or even-aged groups, often pure but frequently in mixture with other species. It develops slowly in the juvenile stage but after 10 or 15 years makes rapid growth both in height and diameter unless the stand is overstocked. Overcrowding may greatly decrease diameter growth. Where red pine is overtopped by jack pine, its growth and development will be retarded. Height growth normally is most rapid between the twenty-fifth and sixtieth years, but tapers off sharply after trees reach 80 to 100 years of age (table 10). Diameter growth continues to be reasonably good for some time thereafter if the trees have plenty of room to grow.

Board-foot increment in unmanaged stands culminates at about 140 years on all sites according to Woolsey and Chapman (*38*). Table 10 places culmination at 120 years for average sites. The latter agrees with the authors' observations, although the mean annual growth was found to culminate at 93 years (*27*) on a plot in mixed red pine-jack pine for which long-time measurements at the Cloquet Forest Experiment Station are available. After about 120 years, diameter growth slows down but the high quality of the wood produced on older trees may compensate for this decrease until the trees reach an advanced age. As previously shown under seed-tree cuttings, old trees continue to make good growth where given opportunity to develop full crowns.

Virgin stands range up to 300 years and individual trees may attain considerably greater ages but a rotation which calls for the final removal cut at approximately 140 years is believed to be about right for sawlog management. In the earlier days of American forestry, this would have meant that no returns would be possible until the stand approached rotation age. This situation no longer prevails although many foresters fail to appreciate the opportunities for intermediate cuttings now afforded by the present markets. Red pine begins to yield money returns at 40 years or earlier through thinning. From that time on until the final tree is harvested, the stand, through management, can be made into a timber-growing "factory."

Periodic, light intermediate, and partial harvest cuttings for a variety of products increasing in value with size enables the forest to produce almost continuously until the rotation ends. Some stands opened up by wind or ice storms may have to be cut earlier, others may need to be held longer in order to wait for reproduction, because

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especially large timber is desired, or during periods when prices are low. The characteristics common to red pine, viz, its long life span, its soundness, and its good growth at advanced ages when it has adequate space, all combine to give flexibility in management.

TABLE 10.—*Yields per acre of well-stocked, unmanaged stands of red pine, by age and site*

Age (years)	Average diameter	Average height of dominants	Total trees per acre	Total basal area	Merchantable yield [1]			
					5 inches and over		8 inches and over, Scribner net	Additional cords (small trees and tops)
	Inches	*Feet*	*Number*	*Square feet*	*Cubic feet*	*Cords*	*Board feet*	*Cords*
GOOD SITE								
20	3.8	24	1,330	106	300	4	1,000	1
30	6.2	37	640	134	1,100	15	3,500	3
40	8.0	49	433	151	2,400	33	7,500	8
50	9.4	60	336	162	3,700	50	12,000	12
60	10.7	69	272	170	4,600	62	16,500	15
80	12.7	82	204	179	5,850	76	23,500	19
100	14.1	93	170	184	6,600	86	27,500	20
120	14.9	100	154	186	7,050	94	30,500	21
140	15.5	104	143	187	7,350	98	32,500	21
160	16.0	106	135	188	7,550	100	34,000	22
AVERAGE SITE								
20	2.6	19	2,370	88	100	1	---------	1
30	4.5	31	1,020	112	750	10	1,000	5
40	6.2	43	625	130	1,550	22	3,000	11
50	7.5	52	470	144	2,350	33	5,500	14
60	8.7	60	370	153	3,000	42	8,700	16
80	10.5	72	275	165	3,950	55	13,500	18
100	11.8	80	228	173	4,600	63	17,000	19
120	12.7	85	200	176	5,000	68	19,000	19
140	13.2	88	186	177	5,300	71	20,500	20
160	13.5	89	180	178	5,500	72	21,500	20
POOR SITE								
20	1.6	15	4,800	68	---------	---------	---------	---------
30	3.3	24	1,610	95	400	6	---------	6
40	4.6	33	955	110	1,000	14	500	12
50	5.8	40	680	125	1,600	23	1,700	15
60	6.8	46	540	136	2,100	29	3,500	16
80	8.5	55	383	151	2,850	39	7,000	18
100	9.6	62	315	159	3,300	44	9,200	18
120	10.3	65	280	162	3,500	47	10,800	19
140	10.7	67	262	164	3,550	48	11,600	19
160	10.7	68	260	164	3,600	48	12,000	19

[1] Units of volume and standards of merchantability follow:

Cubic feet—Cubic-foot volume is the gross volume, excluding bark of trees 5 inches and larger in diameter breast high, to a top diameter of 4 inches inside bark.

Cords—Cord volume includes the same material for which cubic-foot volume is computed, piled with the bark on, in standard cords 4 x 4 x 8 feet.

Board feet—Board-foot volume is the net volume (straight and sound basis) of trees 8 inches and larger in diameter at breast height. Top diameters are variable, the minimum being 6 inches inside bark. The volumes given have been reduced by 15 percent for woods and mill cull.

SITE QUALITY AND ECOLOGICAL SUCCESSION

Relative site quality which governs yield may be determined from Brown's site index graph (*5*) for natural stands given in figure 18. Heights read from this chart seem to fit very well the various condi-

tions found in Minnesota. In fact, they may well apply elsewhere in the country where red pine is found. For example, the height data presented by Reed for Central New England (*24*) when grouped for both medium and poor soils (red pine does not occur naturally on good soils) are very close to those given by Brown for average sites.

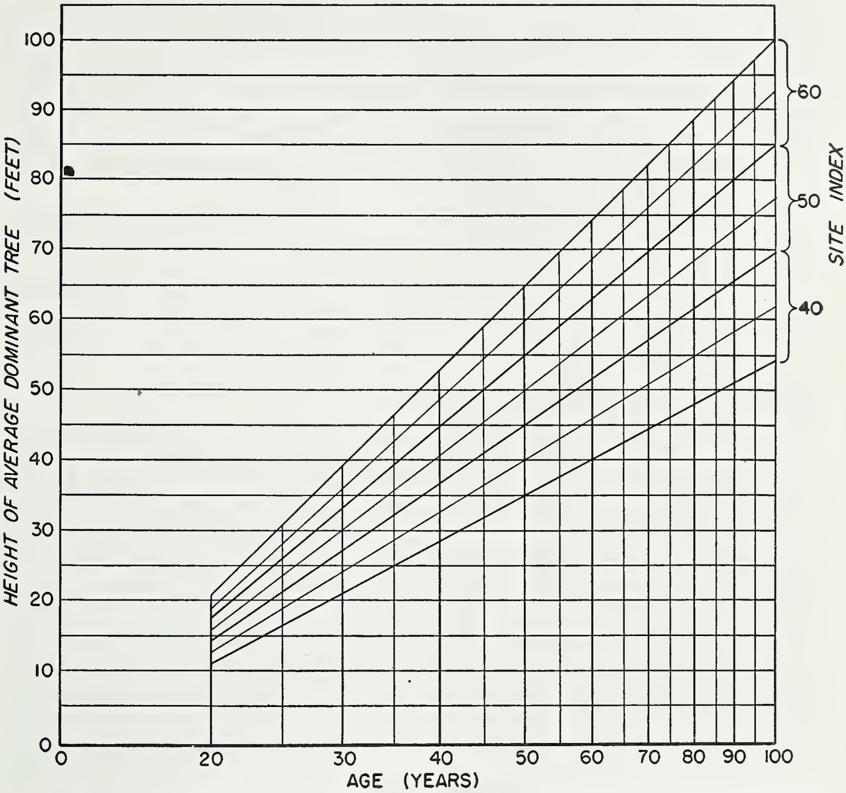

FIGURE 18.—Graph for determining site index of fully stocked, pure, even-aged stands of red (Norway) pine in Minnesota (*from Brown and Gevorkiantz 5*).

Aside from the relation of site quality to yield, site has another important bearing on forest management. On the better quality sites there is usually a considerable proportion of white pine and on the poorer sites more jack pine. In the absence of fire or other catastrophe, the ecological succession is from jack pine to red pine to white pine and finally to hardwoods no matter what the soil (*18*), but the speed of change is likely to be more rapid on the better sites. "Red and white pine establish themselves not only in the more open stands of jack pine but also in those well stocked" (*6*) if the brush undergrowth is not too dense.

Red pine stands seem to provide ideal conditions for the seeding-in of white pine if seed trees of the latter are present. It takes place most often where the stocking is good. This is a desirable tendency on good sites but not on lower quality sites which are poorly adapted

to the best growth of white pine. Natural conversion to white pine, however, is much to be preferred to brush invasion which occurs on understocked areas. Brush growth is, of course, more rank on good sites than on poor ones; hence, the medium and lower quality sites are usually easier to reproduce.

Fire has had a profound influence on red pine forests. By consuming organic matter in the soil, fire has reduced site quality over extensive areas. Repeated burnings have changed many red pine-jack pine types to pure jack pine. Fire will wipe out seedling and small sapling stands of red pine but with advancing age red pine becomes more and more fire resistant—much more so than white pine. Old-growth trees although repeatedly injured by fires are usually sound beneath the charred "cat faces." This resistance is attributed by some to the impregnation of the wood with resin (*35*).

Fire can even be of benefit to red pine. If a surface fire runs through a mature stand just before a good seed year, it may effectively prepare the ground for reproduction (fig. 5). Many even-aged stands are of such an origin. Fires thus sometimes keep down the brush—the worst enemy of red pine reproduction. With the better fire protection that has prevailed in recent years the brush appears to be denser and to cover larger areas than formerly. Once brush takes over, red pine reproduction has practically no chance.

Mixed stands, although influenced by long-time ecological trends are probably more the result of accident than anything else. Mixed stands are ordinarily considered safer risks from insect and disease hazards. White pine, which so often occurs in mixture, is much more susceptible to decay than red pine unless the trees are particularly thrifty. White pine, to succeed, must receive protection from blister rust (*Cronartium ribicola*), a serious disease. Jack pine in mixture with red pine is a more desirable combination. Since jack pine in its youth grows faster than red pine on most soils, its presence speeds up the time when profitable thinnings may be made. Thinnings and improvement cuttings properly carried out not only reduce the investment in the stand but can be very helpful in molding a stand for future development of high-quality timber.

STOCKING AND YIELD

With red pine, as with most forest trees, stocking is the most important factor influencing productivity. Without a substantial capital of growing stock, the growth per acre cannot be large. Open-grown scattered trees individually may grow rapidly but unless they are numerous enough to form a good stand, the yield per acre is bound to be low. A normal yield table for average sites was published by Brown in 1934 (*5*). This table shows basal areas of 171 square feet per acre at age 30 up to 244 square feet at age 100, and 11,000 board feet, Scribner, at age 50 up to 40,000 board feet at age 100. These data for so-called fully stocked stands, like many of the yield tables prepared throughout the country, represent greatly overstocked forests such as are unattainable in nature except under unusual conditions.

Table 10, recently compiled by S. R. Gevorkiantz from unpublished data by Richmond [22] comes closer to expressing conditions in natural unmanaged stands.

Table 11, prepared from 17 permanent sample cutting plots, for stands varying in age from 20 to 140 years, the growth for which has been followed for a considerable number of years, shows yields for managed stands on average sites. So far as is known, this is the first attempt in the United States to present a yield table for managed stands. As experience is gained and more data are available, it should be possible to refine the figures for average sites and to expand the table to include good and poor sites. It is believed that table 11 will be very helpful to the forest manager in pointing out desirable stocking for best yield.

TABLE 11.—*Stocking and yield per acre by 10-year periods for well-stocked, managed stands of red pine on average sites*

Age (years)	Average diameter	Average height dominant tree	Trees per acre [1]	Basal area per acre [1]	Volume [1]			Periodic yield including intermediate cuttings		
	Inches	*Feet*	*Number*	*Square feet*	*Board feet* [2]	*Cubic feet* [3]	*Total cords* [4]	*Board feet*	*Cubic feet*	*Additional cords* [5]
20	2.9	19	1,500	70						
30	4.0	31	1,100	95		375	5			
40	4.9	43	830	110	1,500	632	19	500	268	5
50	5.9	52	620	118	4,200	1,684	27	1,300	550	6
60	6.9	60	470	122	7,800	2,586	33	1,400	476	5
70	8.0	67	350	122	11,000	3,238	37	1,800	543	4
80	9.1	72	270	121	14,000	3,790	40	2,000	544	3
90	10.0	77	220	119	16,000	4,018	42	2,500	637	2
100	10.9	80	180	117	16,700	3,968	43	3,300	793	2
110	11.8	83	150	113	16,300	3,706	42	4,000	914	2
120	12.7	85	120	105	14,700	3,236	41	5,000	1,097	2
130	13.8	87	50	52	8,100	1,827	33	9,600	1,955	5
140	15.0	88	(6)	(6)	(6)	(6)	(6)	9,600	1,955	5

1 Left as growing stock at beginning of each period after cut is made. In stands 80 years of age and older no trees smaller than 8 inches diameter at breast height are included in the growing stock.
2 Reduced 10 percent for defect.
3 Trees 5 inches diameter at breast height and larger to a 4-inch top diameter inside bark excluding bark and 1-foot stump.
4 Trees 5 inches diameter at breast height and larger including bark, to a 5-inch top diameter inside bark for total stand.
5 In addition to yield in board feet. Made up of small trees under sawlog size taken out in thinnings and tops of sawlog trees.
6 Clear cut at age 140.

The stocking recommended is believed to be low enough in the younger age classes to prevent stagnation yet great enough to bring about some natural pruning. There are sufficient stems to make possible early commercial thinnings and intermediate cuttings in middle-aged stands. For the older stands the stems are reduced in number to provide the greater growing space needed late in the rotation. Possible supplementary yields under management which include those from intermediate cuttings are also given. Although the growing stock is held to a much lower level than occurs in natural unmanaged stands, the total yield under management for the rotation is much the greater because of more rapid growth and the volume obtained from intermediate cuttings. This is brought out in figure 19.

22 Richmond, Howard H. Growth and yield of Norway pine. U. S. Forest Service, 1916. [Unpublished manuscript.]

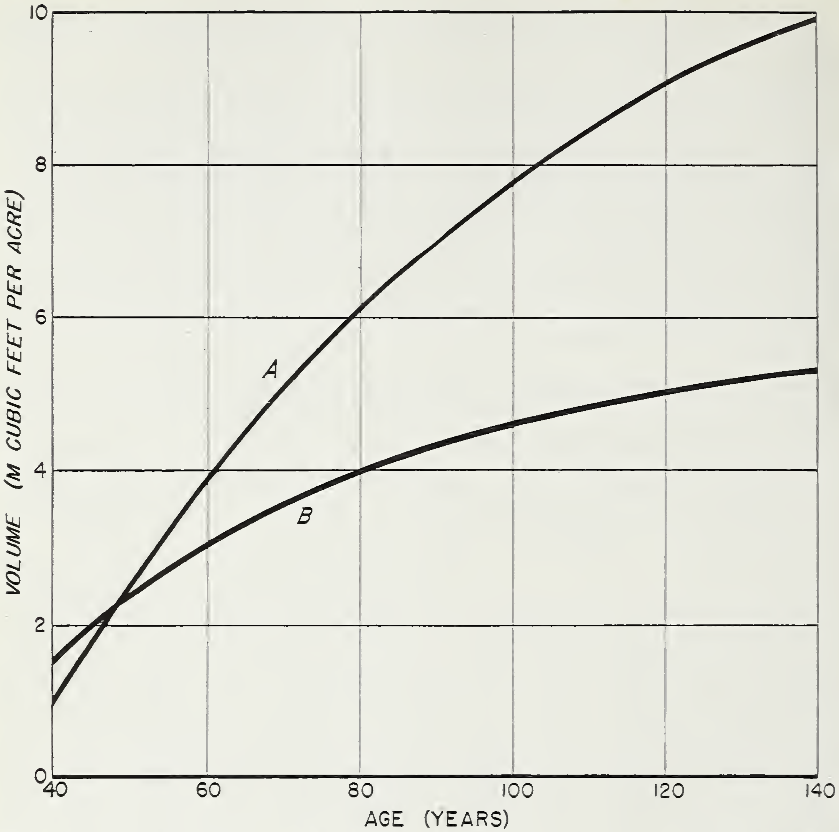

FIGURE 19.—Comparison of yields in cubic feet per acre from unmanaged and managed stands. *A*, Managed stands—current stocks plus sum of yields from periodic cutting (table 11). *B*, Unmanaged stands—accumulation of growing stock without cutting (table 10).

INFLUENCE OF INSECTS, DISEASES, AND ANIMALS [23]

Where red pine occurs naturally in fairly extensive stands such as in Minnesota, it has always been considered one of the most insect- and disease-resistant trees. The red-headed sawfly (*Neodiprion lecontei*) occasionally has caused local damage to natural reproduction but is much more injurious to planted stands. Extensive damage to plantations from this cause has been reported from Michigan, but very little from Minnesota where this sawfly has shown a marked preference for jack pine. In mixed plantations jack pine has been completely eliminated before there is much evidence of infestation on red pine.

Trees weakened by drought or storm injuries are sometimes attacked by pine sawyer beetles (*Monochamus* spp.). A bark beetle (*Ips*

[23] Acknowledgement is made to A. C. Hodson and Clyde M. Christensen of the University of Minnesota and to L. W. Krefting of the United States Fish and Wildlife Service for their help in preparing this section. The information on animals was largely obtained from Aldous, Shaler E. SOME FOREST-WILDLIFE PROBLEMS IN THE LAKE STATES. United States Fish and Wildlife Service in cooperation with Lake States Forest Experiment Station. Station Paper No. 6, 1947. 11 pp. [Processed.]

pini), after breeding in windthrown trees or tops of trees left in logging operations, sometimes attacks living trees and kills weaker specimens. The presence of *Ips* usually indicates low vigor or overmaturity. The red turpentine beetle (*Dendroctonus valens*) which is found around fire scars and other injuries particularly on mature and overmature trees also indicates poor vigor.

A number of other insects are of occasional importance. The pine bark aphid (*Pineus strobi*) occurs on new growth of young stock. The pine root-collar weevil (*Hylobius radicis*) has occasionally killed natural and planted trees 8 to 12 years old. The jack pine budworm (*Archips fumiferana*) has caused severe damage to young red pines growing beneath overmature jack pine. A branch gall weevil (*Podapion gallicola*), fairly common on both young and old trees, sometimes kills branches. The larvae of the pine pitch moth (*Pinipestis zimmermani*) have caused heavy fall of new shoots from mature trees. Cone-infesting insects sometimes destroy a very high proportion of the cones and thus reduce natural reseeding even in years when there would otherwise be a good crop of seed.

Of more consequence is the Saratoga spittle bug (*Aphrophora saratongensis*) which has during recent years killed considerable planted jack pine and red pine according to Secrest (*31*). So far the damage has been mostly in Wisconsin and Michigan, but the insect has also been found in Minnesota. Whether it will continue to spread remains to be seen, but it appears to be a threat to young stands up to 15 feet in height. The adult attacks small tip and lateral branches of pines by sucking the sap, causing dessication and a girdling effect. The branches are killed after repeated attack. The nymphal stage feeds chiefly on sweet fern (*Comptonia peregrina*) and some other shrubs and herbaceous plants. Encouragement of closed stands which shade out and suppress the undergrowth and ground cover, deprives the nymphs of their host plants, and thus helps to hold the insect in check.

More recently Anderson (*2*) working in Wisconsin made extensive studies of the nature of the injury of the Saratoga spittle bug. The adult insects were found to feed on the needle-bearing portions of the branches. The insects withdrew large quantities of water and in addition the injuries they caused apparently interfered with water conduction. His study showed that the initial breakdown of the phloem tissue appeared to be due to salivary toxins injected by feeding insects. Where red pine and jack pine were growing together the former was more heavily attacked. The possibility of controlling the insect in plantations by airplane spraying with DDT and other insecticides is now undergoing extensive field tests.

Burn blight caused by *Chilonectria cucurbitula* follows spittle bug attack and causes extensive damage and killing of jack pine and red pine according to Gruenhagen et al. (*14*). The damage has been reported mostly in plantations. The organism is said to be dependent on some injury such as punctures made by spittle bugs for entry. The usual pattern is for the disease to start in the twigs and in the upper part of the tree and to work toward and down the main stem. The disease progresses more slowly in red pine than in jack pine. Red pines have been observed to recover more frequently than jack pines. The disease is more damaging to the less vigorous trees and to trees on poor sites than on good sites.

Red pine is very sound but an occasional overmature tree contains some rot as a result of action by *Fomes pini* and *Polyporus schweinitzii*. These fungi are far more aggressive in both white pine and jack pine than in red pine.

Armillaria mellea occasionally is found invading the inner bark and cambium of the roots and lower trunk of dying and recently dead trees. A survey in the Chippewa National Forest in 1934 [24] indicated that the fungus was generally present in the soil. Recent evidence from unpublished work by A. C. Hodson and Clyde M. Christensen strongly suggests that *Armillaria mellea* is a secondary invader and that it will cause little damage on trees of normal vigor.

Moderately severe infections of leaf rust, caused by *Coleosporium solidagins*, have occurred in limited areas in a number of plantations, but the defoliation apparently has not been heavy enough to cause any reduction in growth. Two canker-forming rusts (*Cronartium comandrae* and *C. comptoniae*) and the pine-oak gall rust (*C. cerebrum*) infect red pine, but none of these is known to have caused any significant loss in natural stands or plantations in Minnesota.

A number of different mammals and birds damage red pine. The snowshoe hare (*Lepus americanus*) during periods of peak population feeds extensively on young conifers including red pine. The nipping done by these animals may kill young red pine seedlings but other species of pine are damaged more than red pine. Plantations are injured more than natural reproduction.

The white-tailed deer (*Odocoileus virginianus*) is also destructive to red pine seedlings and planted trees although less than to jack pine. Their numbers do not fluctuate greatly from year to year like the hare, but their browsing extends over a longer period since they clip the trees as long as they are within reach. Some trees are killed; others are deformed or retarded in growth.

The porcupine (*Erethizon dorsatum*) does considerable damage to red pine stands on occasion. By feeding on the bark it girdles and kills many trees 10 or 15 feet up to 40 feet tall or even larger. The animal seems to prefer the more open-grown trees where they can least well be spared from the stand. A single animal may cause much trouble because it works a long time in one location. Areas well-supplied with natural dens such as are provided by overhanging rock ledges or roots of windthrown trees appear to harbor the greatest population of porcupine.

Mice, especially the white-footed mice (*Peromyscus* spp.) and chipmunks eat large quantities of pine seed. Birds such as the goldfinches, juncoes, and many others also consume pine seed. At times the red squirrel (*Tamiasciurus hudsonicus*) reduces the seed crop by cutting the tips of mature trees (*9*), removing considerable quantities of first-year cones (*28*).

PRUNING

With the possible exception of tamarack (*Larix laricina*), red pine prunes itself naturally the best of any conifer native to the Lake States. In contrast to white pine, red pine cleans itself remarkably well. Lower limbs die as soon as the crowns close and by the time

[24] Christensen, Clyde M. A REPORT ON THE PREVALENCE AND IMPORTANCE OF ROOT ROT OF FOREST TREES IN MINNESOTA. [Unpublished.]

the stand has reached an age of 25 or 30 years, many dead limbs have dropped off. Even so, very little knot-free lumber will be produced in rotations less than 80 to 100 years and this only where stocking is fairly good. Natural pruning is all that is required for the production of material used in the round, but in order to grow clear lumber in short rotations, artificial pruning is a necessity. The more open the stands, the greater is this need, but open stands cost more to treat.

Almost no experience in pruning of red pine in Minnesota was had prior to the advent of the Civilian Conservation Corps in 1933. During the following 8 years, a considerable acreage of red pine was treated in this manner. A final appraisal of results must await many years, but observations thus far indicate that red pine reacts very well to artificial pruning. After 6 or 8 years, pruned trees still retain pitch formations at points of branch serverance. These balls of pitch, however, are superficial and may be easily rubbed off. Underneath, solid bark and wood have grown over the wounds. This agrees fairly closely with Paul's report *(21)* of studies made in New England that an average of 5 years is required for pruned red pine to heal over.

Bickerstaff [25] in his studies in Canada found that pruning to a height of 8 feet in 18-year-old planted red pine on good site affected the growth rate but slightly and that pruning tends to decrease taper. Paul *(23)* suggests that severe pruning could be used as a device to check excessive diameter growth and thus produce wood of better quality.

Considering the expense involved in artificial pruning, the greatest care must be exercised in selecting the proper trees for treatment. Obviously no tree should be pruned that will be taken out in thinnings or intermediate cuttings or that is grown for products other than saw-logs; to do so would be lost effort. Probably 100 final crop trees per acre or perhaps even fewer will be enough to prune on fairly well-stocked areas of red pine. These should be dominant, fast-growing trees of good form. Pruning offers the best prospect of paying dividends when confined to the best sides. The longer internodes require the removal of fewer branches and thus lower the cost per lineal foot of clear stem.

Rarely will it be found desirable to prune more than one 16-foot log length above stump height. The first log contains about half of the board-foot volume in average second-growth saw-timber trees and it is the butt log that puts on the greatest diameter growth. Moreover, pruning costs mount rapidly above 16 or 18 feet because of the necessity of using long, unwieldy pole saws or ladders to reach the higher limbs.

Pruning to the top of the first 16-foot log can best be done in 2 or 3 operations with ordinary hand-operated pruning saws. Trees should preferably be not over 3 or 4 inches diameter at breast height with branches under 1 inch in diameter when pruning is started. The first operation should prune to about one-half the height removing about one-third of the living crown during the dormant season. Subsequent operations should push the crown up to a height of 17 feet, using a pole saw. In all cases the pruning should be flush with the tree boles to insure prompt healing. Red pine is also adapted to the finger-

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[25] Bickerstaff, A. Effect of thinning and pruning upon the form of red pine. Silvicultural Research Note No. 81, Dominion Forest Service, Ottawa, Canada, 1946. [Processed.]

budding or "Russian" method of pruning in which the lateral buds are removed annually (*12, 22*). To date this method is considered entirely experimental and cannot be recommended for general practice.

Whether pruning will pay out as an investment is, of course, somewhat speculative. It all depends on the future difference in price in lumber grades and the cost of pruning. It has been shown that pruning of eastern white pine in New England is profitable for rotations of 60 years or less (*11, 15*). With the growing scarcity of high-grade lumber, some pruning of red pine would seem to be justified under intensive management.

Thinnings

Through thinning it is possible to mold a stand. By discriminating against the less desirable components, species composition may be governed; and by regulating the density of stocking diameter growth may be directly controlled. Density also affects natural pruning. In any stand of timber individual trees always vary greatly in growth rate, form, and other characteristics. Some of the variability is due to injuries from insects, animals, or weather, but much is probably the result of inherent genetic differences. By using care in tree selection in thinning operations, it is possible to eliminate undesirable specimens and to carry through to maturity those of best form and quality.

TREATMENT OF DENSE SAPLING STANDS

Occasionally, due to a combination of circumstances, viz, plentiful seed, a good seedbed, and favorable weather, red pine reproduces abundantly and exceptionally dense sapling stands develop at an age of 15 or 20 years (fig. 20). Such stands may contain as many as 5,000

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FIGURE 20.—Dense 20-year-old red pine in need of thinning. Cut Foot Sioux District, Chippewa National Forest, Minn.

trees per acre and in extreme cases up to 20,000 (*17*, *29*). Sapling stands of less than about 2,500 stems per acre appear able to thin themselves, but denser ones are subject to stagnation according to Kittredge (*17*).

Given plenty of time, stands approaching 2,500 trees per acre may thin out naturally, but in any case their diameter growth rate will be retarded. Accordingly, early thinning of dense saplings may be a necessity for optimum stand development. Under present market conditions in Minnesota, such thinnings can be made only with a cash outlay since the products obtained will not pay the cost of the operation. Where a fuel wood market exists, part of the cost of early thinning may be met. Moreover as the market for small posts improves, early thinning may be possible without any expense whatever and perhaps even at a small profit.

In an experiment at the Cloquet Forest Experiment Station, started in 1927, Schantz-Hansen (*29*) established $\frac{1}{10}$-acre thinning plots in a 15-year-old red pine stand. These plots were thinned to spacings of approximately 4 by 4, 6 by 6, 7 by 7, and 9 by 9 feet from densities of 13,000 to 20,000 trees per acre. The plots used in the test classify in the lower portion of the 40-foot site index (fig. 18). During the 15 years after thinning, there was little loss of trees on the thinned plots, but natural competition on the check area had taken a rather heavy toll. Even so, the check plot still had 8,480 living trees per acre. Thinning may have increased height growth slightly, but acceleration in diameter growth was quite marked, particularly in the 9- by 9-foot plot and next in the 7- by 7-foot plot. The average diameter at breast height of trees on all plots having spacings 6 by 6 feet or wider did not vary greatly, however. In an ecological study of these same plots (*8*) it was concluded that 6 by 6 plantations could be left to grow until at least 25 years old, without need for thinning.

A thinning experiment initiated in 1927 in 23-year-old red pine on the Chippewa National Forest sheds additional light on the treatment of dense sapling stands. These plots, like those at Cloquet just described, classify in the lower portion of the 50-foot site index and in the upper portion of the 40-foot index (fig. 18). Although the plots are small, ranging from one-tenth to two-tenths of an acre in size, and were damaged by glaze in 1940, records have been taken on their behavior over quite a number of years so the results should be fairly reliable.

At the time of thinning, the stand supported from 2,800 to 5,600 saplings per acre from 1 to 2 inches in diameter. The plots were thinned to approximate spacings of 6, 8, and 10 feet, respectively, and one plot was left untouched for comparison. Table 12 gives the precise spacings in 1927 and in 1944. The growth and mortality over the 17-year period are shown in table 13. Analysis of the growth by periods (1927 to 1937 and 1938 to 1944) brings out the fact that growth in cubic feet in plots having wider spacings is now increasing whereas that on the 6-foot spacing (now 7.2 by 7.2 feet) and check plot (now 4.6 by 4.6 feet) is declining rapidly. This decrease in growth rate in the more densely stocked plots could, no doubt, be changed by a commercial thinning for pulpwood which could probably now be made at a profit. The check plot still has the greatest volume both in cords and in cubic feet, but is on a slightly better site than the others. The trees on the check area are under-

going natural pruning and the plot is rapidly thinning itself. The thinned plots have lost comparatively few trees except for those broken by the glaze of 1940.

TABLE 12.—*Number of trees, basal area, and volume per acre of thinned red pine, 1927 and 1944*

Item	10-foot spacing		8-foot spacing		6-foot spacing		Check plot	
	1927	1944	1927	1944	1927	1944	1927	1944
Average spacing [1] ... feet	9.9	10.7	7.8	8.1	5.9	7.2	3.6	4.6
Trees ... number	445	379	710	660	1,254	837	3,360	2,080
Basal area ... square feet	19.9	83.4	27.3	107.2	32.4	99.6	108.1	151.9
Volume:								
Peeled, including stump and top ... cubic feet	202	1,247	267	1,571	294	1,405	1,104	2,379
Unpeeled, to a 3-inch top diameter inside bark ... cords	-------	16.3	-------	20.3	-------	17.4	-------	24.4
Height of average dominant tree ... feet	22	38	21	37.5	20	36	23	41

[1] Wider spacing in 1944 is due to mortality, mostly caused by 1940 glaze.

TABLE 13.—*Growth and mortality per acre of thinned red pine, 1927–44*

Spacing (feet)	Net growth			Mortality				Mortality due to 1940 glaze storm			
	Basal area	Volume		Trees	Basal area	Volume		Number of trees	Basal area	Cubic feet	Cords [1]
		Total peeled volume including stump and top	Unpeeled to a 3-inch top diameter inside bark			Total peeled volume including stump and top	Unpeeled to a 3-inch top diameter inside bark				
	Square feet	*Cubic feet*	*Cords*	*Number*	*Square feet*	*Cubic feet*	*Cords*	*Percent*	*Percent*	*Percent*	*Percent*
10	63.5	1,045	16.3	66	4.3	48	0.4	65	84	85	100
8	79.9	1,304	20.3	50	3.6	42	.2	80	78	81	100
6	67.2	1,111	17.4	417	20.9	252	.8	89	96	97	100
Check plot	43.8	1,275	24.4	1,280	31.2	387	2.1	27	64	70	100

[1] No trees of cordwood size (4 inches diameter at breast height and up) died from causes other than glaze.

The heavier thinnings have considerably stimulated diameter growth. The 8- and 10-foot plots have many more trees of larger diameter (table 14) than have the 6-foot and the check plots. The 10-foot spacing, for example, has 47 trees per acre in the 8-inch diameter at breast height class of suitable size for small telephone poles; the 8-foot spacing (fig. 21) has 10 trees per acre in the same size class, but there are no trees as large in either the 6-foot plot or the check area. The 8- and 10-foot plots have suffered less from glaze than closer-spaced ones. Mulloy,[26] in studies of thinnings in young red pine plantations in Canada, also observes that early thinning reduces damage from ice storms because the thinned trees are more sturdy. In these Canadian studies where the plots were on very good site, thinning 24-year-old plantations containing about 1,000 trees per acre to spacings slightly greater than 8 by 8 feet greatly

[26] Mulloy, G. A. Thinning red pine. Silvicultural Research Note No. 79. Dominion Forest Service, Ottawa, Canada. 1946. [Processed.]

stimulated diameter growth. For special products such as poles, it is desirable to strive for fairly open-spaced stands. Such spacing increases taper, an added advantage in pole production.[27] On the basis of the original data given here and results elsewhere, the conclusion is that early thinnings can successfully be used to shorten the rotation age when merchantable material can be produced.

TABLE 14.—*Trees per acre in 1944, 7 inches diameter at breast height and larger by 1927 spacing*

Spacing in 1927 (feet)	Trees per acre in 1944		
	7 inches diameter at breast height	8 inches diameter at breast height	Total
	Number	*Number*	*Number*
10 by 10	109	47	156
8 by 8	160	10	170
6 by 6	15		15
Check plot	30		30

Heavy thinning, however, is done at the expense of quality when the timber is to be used for sawlogs. For best quality, pine timber should have steady, even growth, and the rings should not be too wide (*23*). Such timber cannot be grown in open stands. In the wider spacings in the Chippewa plots, the limbs are heavier and are lower down on the boles than where the spacing is closer. The height to the first green limb varies from 13 feet on the 10-foot spacing to 17 feet on the

F-392265

FIGURE 21.—A 32-year-old red pine stand thinned at the age of 20 to a spacing of 8 by 8 feet. Thinning has resulted in a remarkable diameter acceleration but stocking is not thick enough to warrant thinning for pulpwood. Cut Foot Sioux District, Chippewa National Forest, Minn.

[27] See footnote 25 on page 39.

check area. The diameter of the average live limb in the lowest 8 feet of crown ranges from 0.82 inch on the unthinned plot to 1.29 inches on the most open plot with many limbs on the latter being as large as 2 inches in diameter.

The open-spaced trees, especially those on the 10- by 10-foot plot, now need artificial pruning if they are to produce saw timber of good quality but probably do not need it if they are to be used for poles and other products such as piling, where knots are less objectionable. A further disadvantage of the 10- by 10-foot thinning is that the additional light has encouraged the growth of brush and grass which will add to reproduction problems in the future. Encroachment of vegetation is not very noticeable in the 8- by 8-foot or lighter thinnings. The 6- by 6-foot plot (now actually 7.2 by 7.2 feet) shows about the best all-around results. Unless it is necessary to force diameter growth to develop some special product, there would seem to be no need of making a cash outlay for thinning sapling stands to spacings less than 6 by 6 feet on average sites. Even slightly closer stands should develop satisfactorily. By the time stands growing at such spacings begin to tighten up too much, a light pulpwood thinning will again provide sufficient growing space for good stand development.

As an aid to thinning practice, Wilson (*37*) advocates the use of a numerical expression of stocking in terms of height. He states that height has the virtue of combining the components of age and site in one measurement, a decided advantage to any index. For the Chippewa plots, the spacings expressed in percent of average height of dominant trees are as follows:

	Relation to average height of dominants	
	1927 (percent)	*1944 (percent)*
Spacing (feet):		
10 by 10	45	28
8 by 8	37	22
6 by 6	29	20
Check plot	16	11

Taking the 6- by 6-foot thinning as an example, the thinning to 29 percent of height in 1927 probably represented too wide a spacing the first few years after treatment. The same stand in 1944, however, spaced at 20 percent of height, has approached the time for a pulpwood thinning.

These figures show the desirability of aiming at spacings between one-fourth and one-fifth of height for trees 20 to 40 years old. For stands older than 40 years, it is suggested the figure should be a little less than one-fifth the height but it is not believed that this factor should be used as a constant throughout the life of a managed forest of red pine. This rule is most easy to apply. Such spacing guides are very useful but it should be cautioned that in actual practice precise spacings should not be the main objective. Instead, every effort should be made to leave the most promising trees and to eliminate the poor ones even though they stand at the right spacing.

As a general objective, any noncommercial thinning should reduce the number of stems to the maximum that can be carried with reasonably good growth until a commercial thinning can be made. The number of trees to carry will depend on market and site quality. For average sites in Minnesota, 800 to 1,000 stems per acre represent desirable stocking at the age when the first commercial thinning for

pulpwood is possible. On better sites, the number should be less since better growing conditions permit the trees to make faster growth and fill up the openings more quickly. On poorer sites more trees should be retained in order to make better use of the available space.

COMMERCIAL THINNINGS FOR PULPWOOD

Due to lack of specific information on commercial thinning in natural stands, some data on planted stands are suggestive as to desirable practice. A thinning in a plantation in Wisconsin at age 30 reduced the number of trees from 836 to 580, the basal area from 174 to 140 square feet, and the volume from 36 to 31 cords per acre with benefit to the remaining stand. The operation was carried on at a profit (*36*).

The great possibilities of producing pulpwood by thinning red pine plantations, beginning at about age 30, have also been recorded in New York (*19*). A plantation on the Superior National Forest of about the same age and site as the one in Wisconsin cited above, planted 8 by 8 feet (680 trees per acre), does not need thinning. This plantation is in a very thrifty condition and the trees have all the growing space they can utilize so the first returns must be delayed until material larger than pulpwood can be grown.

These observations and tests indicate that a pulpwood thinning should reduce stocking to about 600 to 750 trees per acre on good sites. On average sites it is recommended that such commercial thinning reduce the number of trees to about 825 per acre with a range from 750 to 900.

Well-spaced plantations will produce pulpwood in 30 years. Natural stands with their usual uneven or patchy distribution and hence slower diameter growth within the groups may require 30 to 35 years on good sites and 40 years on average sites. The sooner the thinnings can be started thereafter the better, because of the tendency for overstocked red pine to stagnate. This stagnation in stands which were only lightly thinned is well illustrated by plantations established in 1900 and 1901 near Grand Rapids, Minn. (*1*). These red pine plantations, incidentally, are the oldest in the State.

Pulpwood thinnings in pure red pine should generally be "from below," that is, the trees removed should be the smaller, weaker ones that have less chance for survival. However, in order to carry on the first thinning as early as possible, it will usually be necessary to thin partly "from above" and "from the side." Otherwise, there will not be enough stems of commercial size for pulpwood among the subordinate trees of the stand. By repeating thinnings at 5- to 10-year intervals, trees which would otherwise die are salvaged; misshapen, wolfy trees are eliminated; and the total yield over the rotation in both volume and quality is greatly increased.

Thinning of mixed stands affords an opportunity to control composition. The most common mixture is red pine and jack pine. Discrimination against jack pine assures red pine a place in the future stand, but there is danger of carrying this idea too far. Preservation of some of the fast-growing jack pine will make possible an earlier cut for higher-value products such as box bolts, mine timbers, etc., than

if it is entirely eliminated. Jack pine in mixed stands on average sites will ordinarily reach pulpwood size in 35 years or sometimes earlier (fig. 22). In mixed stands, the first thinning will of necessity be mostly from above. Most of the cut will be jack pine. Some of the ill-formed red pines, however, may also be removed in this operation if they are large enough to be merchantable. In such commercial thinnings, attention must be focused on trees to be left rather than on those to be taken out. In the first commercial thinning the canopy should be opened cautiously so that it will close again in about 5 years. Thinnings that remove only 3 to 5 cords per acre give promise of soon becoming feasible economically.

F-39229

FIGURE 22.—Taking out jack pine for pulpwood in a 30-year-old mixed red pine-jack pine stand near Norway Beach, Chippewa National Forest, Minn.

INTERMEDIATE CUTTINGS IN MIDDLE-AGED STANDS

Although thinnings for pulpwood and other small material will pay their way and often yield a small profit, it is not until the stands reach an age of 45 or 50 years that red pine is large enough to offer attractive possibilities for intermediate cuttings (fig. 23). From that time until they are about 80 years old they are ideal for such cuttings at 10- to 15-year intervals or even more frequently. These cuttings, made primarily with the purpose of improving the forest by removing less desirable species and poorer specimens of the red pine itself, yield more and more valuable products as the trees become larger.

A stand 48 years old on good site near Longville, Minn., on the Chippewa National Forest, cut over in 1942-43 for box bolts and pulpwood, will serve to illustrate possibilities in stands of this age (table 15). This stand contained some mixture of jack pine which overtopped the red pine. The jack pine ranged in diameter at breast

F-432200

FIGURE 23.—A 45-year-old red pine stand following an improvement cutting. Old stumps are still present from the original logging many years ago. New stumps are low and mostly hidden by vegetation. Chippewa National Forest, near Longville, Minn.

height from 6 to 13 inches with an average of 10.2 inches. The red pine ranged from 2 to 12 inches diameter at breast height with an average diameter of 6.9 inches.

TABLE 15.—*Volume per acre before cutting for a 48-year-old stand of red pine in the Chippewa National Forest, near Longville, Minn.*

Species	Trees [1]	Basal area	Merchantable yield			
			Peeled volume (including stump and top)	Volume to a 4-inch top diameter inside bark	Trees 7.6 inches diameter at breast height and up, to a 6-inch top diameter inside bark [2]	Additional volume [3]
	Number	*Square feet*	*Cubic feet*	*Cords*	*Board feet*	*Cords*
Red pine	519	135	2,943	28.4	5,897	18.0
Jack pine	33	19	643	5.9	2,743	1.2
White pine	16	2	47	.3	14	.3
Total	568	156	3,633	34.6	8,654	19.5

[1] Two inches diameter at breast height an over.
[2] Scribner rule.
[3] Trees under sawlog size and tops of sawlog trees to a 4-inch top diameter inside bark.

Sample cutting plots were laid out in this stand, marked in two different ways: (1) an improvement cut from above and (2) improvement cutting from below. In the first case, 3,700 board feet of box

bolts and 3.7 cords of pulpwood were removed per acre and in the second 1,700 board feet of bolts and 3.6 cords. Jack pine made up the larger part of the cut in each instance. More time must elapse before results can be evaluated, but since neither operation reduced the basal area more than 25 percent, it would seem as if either method could be applied with safety.

These plots, totaling 3 acres, represent a well-stocked portion of the stand. Over a larger area, much of which was not as well stocked, the pine timber was marked according to the more conservative of the methods employed on the plots and cut under regular national forest timber sales procedure. In the operation, 26 M feet of sawlogs and 72 cords of pulpwood were cut and sold. In spite of a very light cut per acre, the operator reported a good profit which indicates the practicability of the operation. The stand is left in excellent condition for future growth and development (fig. 23). Another and considerably more valuable cut can be taken out in 10 years, or possibly sooner.

By the time stands reach an age of about 60 years, they contain large volumes of merchantable material in the form of mine timbers and small sawlogs, as well as less valuable products, such as pulpwood. In an effort to determine possibilities of making heavy intermediate cuttings in mixed red and jack pine stands of this character, 4 plots were established on good site on the Chippewa Forest in 1927. The stand was well stocked if not overstocked supporting 608 to 710 stems per acre from 1 inch to 16 inches diameter at breast height, with an average of about 7 inches. Table 16 gives additional details on the stand.

Marking of trees to cut favored red pine at the expense of jack pine. The treatment practically eliminated the jack pine on the cutting plots. It removed from 47 to 58 percent of the saw timber and 39 to 47 percent of the basal area. An additional 6 to 8 cords per acre of pulpwood could have been obtained from tops and from small trees that were cut. A light improvement cutting salvaged sleet-damaged timber in 1940. This, however, removed only about 15 percent as much merchantable volume as the original cutting, mostly in the smaller trees.

The volume per acre removed in the two cuttings, the reaction to the cutting, and the behavior of the untreated plot, as revealed by the subsequent growth and development of the stand, are given in table 16. The diameter growth has been much greater on the cutting plots than on the uncut plot. This largely accounts for the fact that on the areas cut over, the stand in board feet in 1943 had already surpassed the original volume present in 1927. The annual growth for the 16-year period following cutting was 528 board feet per acre. This stand is shown in figure 24. Forty percent of this exceptional growth was due to "ingrowth" of small trees just reaching merchantable size. The growth of this stand in cubic feet and cords perhaps more truly reflects the stand behavior. Despite the reduced growing stock, the periodic annual increment averaged about 1 cord per acre per year of merchantable pulpwood (to a 4-inch top diameter) for the cutting plots compared to a 0.6 cord on the uncut plot. Figure 25 shows the uncut plot.

As another measure of productivity, the piling trees present on the various plots were estimated in 1944. The cutting plots had an

average of 500 linear feet of red pine piling per acre compared to 160 linear feet of jack pine piling (which sells at a much lower unit price) on the untreated plot. Thus there was a financial benefit in the improvement cutting not brought out by the growth data previously given. Notwithstanding the excellent results from this cutting, even better ones from a financial angle would have been possible if the timber had been removed in two or three operations instead of one. Retention of somewhat more growing stock would have permitted many small trees that were taken out in 1927 to put on the extra diameter needed for higher-valued products.

TABLE 16.—*Comparison of volume and growth per acre between a heavy improvement cutting and an uncut plot in 60-year-old red pine-jack pine*

Item	Trees	Basal area	Volume: Peeled volume including stump and top	Volume: Peeled volume to 4-inch top diameter inside bark	Volume: Trees 7.6 inches diameter at breast height and larger to a 6-inch top diameter inside bark [2]	Volume: Small trees and tops of sawlog trees to a 4-inch top diameter inside bark
	Number	*Square feet*	*Cubic feet*	*Cords*	*Board feet*	*Cords*
HEAVY INTERMEDIATE CUTTING [1]						
Original stand, 1927	661	165	3, 775	36. 0	11, 766	14. 5
Cut, 1927 and 1940	271	85	2, 046	19. 9	7, 113	6. 9
Stand, 1943	313	117	3, 293	32. 0	13, 099	8. 3
Total yield to 1943			5, 339	51. 9	20, 212	15. 2
Total growth, 1927–43			1, 564	15. 9	8, 446	. 7
Annual growth, 1927–43			98	1. 0	528	. 04
UNCUT STAND [3]						
Original stand, 1927	654	159	3, 638	34. 8	11, 614	13. 3
Cut, 1927 and 1940						
Stand, 1943	432	161	4, 683	43. 9	18, 060	12. 5
Total yield to 1943			4, 683	43. 9	18, 060	12. 5
Total growth, 1927–43			1, 045	9. 1	6, 446	—. 8
Annual growth, 1927–43			65	. 6	403	—. 05

[1] Based on 3 ½-acre plots, established in 1927.
[2] Board feet, Scribner rule.
[3] Based on 1 ½-acre plot, established in 1927.

Besides the benefit of increased growth in the managed stand, another obvious advantage of intermediate cuttings is the reduction in interest charges by the removal of considerable merchantable value. Still another advantage is the conversion from a mixed red pine-jack pine stand to a pure red pine stand. In order to salvage all of the jack pine possible and to keep mortality low, such conversion should be entirely accomplished by the time the stands attain an age of 80 years. Jack pine is then fully mature and to hold it longer is risky. But red pine is just then reaching a size when selected products will produce greater returns.

F–392267

FIGURE 24.—A 75-year-old stand of red pine on good site which was subjected to a heavy improvement cutting at age 60. This operation removed all the jack pine which was then growing in mixture. Cutfoot Experimental Forest, Itasca County, Minn.

F–392279

FIGURE 25.—Jack pine mine timber and saw timber in need of removal from 75-year-old mixed red pine-jack pine stand. Cutfoot Experimental Forest, Itasca County, Minn.

In this heavy improvement cutting there was no conscious effort to obtain reproduction as it is not needed in well-stocked stands at age 60. However, some interesting facts from the point of view of regeneration were revealed by the experiment. After cutting, there remained 35 red pines per acre over a 10-inch diameter at breast height and a large number of smaller trees. Fair to good seed crops are known to have occurred in 1927, 1930, 1937, and 1943, with probably partial crops in some other years.

A count of reproduction in 1944 showed an average of 9,570 seedlings per acre on the cutting area, 8,485 of which were red pine, 800 jack pine, and 285 white pine. Less than 1 percent of the red pine reproduction established itself during the first 5 years after cutting even though there was a seed crop in 1927. Six percent of the reproduction originated the second 5 years after cutting and an additional 12 percent the third 5-year period. The striking thing is that 81 percent of the reproduction was of 1944 origin following the good seed crop of the previous year. The implications from these data are that space and time are required to develop densely grown 60-year-old trees into good seed producers.

The crowns of trees in stands of this character are very narrow and not large enough in general for heavy seed production. The contrast between the crowns in the cutting plots after 18 years of development and those in an adjacent uncut plot is sufficiently great to explain the lack of immediate reproduction following the 1927 operation and the present abundance. Then, too, the fact that the trees are older now no doubt has a bearing on cone-producing capacity, since it has been observed that red pine appears most capable of producing seed between the ages of 80 and 140 years. More sunlight is now needed to bring through a satisfactory stocking of reproduction on this area. Given favorable weather, a final cut a year or two hence would probably accomplish the desired results although considerable losses of small seedlings from sudden exposure and brush invasion may be anticipated. There would also most certainly be some loss of reproduction in logging. Enlightening as this information is as to the possibilities of reproducing 60- to 80-year-old red pine, it would be most unwise to clear-cut the stand at this age because of the exceptional growth of valuable timber now taking place.

Beginning the Harvest

The first step in the harvest of red pine stands should be taken as they reach an age of about 80 years, when they are entering their most productive period. Growth continues to be good for a number of decades thereafter if the stand has, up to this time, been handled with an eye to the future and is in good condition of thrift. This period may see the beginning of regeneration, but specific efforts to obtain reproduction need not be made until later.

The cuttings thus far recommended have all been for improvement of the stand by the removal of the less desirable species and trees of poor form. It is desirable to continue the removal of the less thrifty trees, taking out small cuts at frequent intervals, but such cuttings need not be made up of the less desirable species nor of red pine of low

value. There will be some high-value timber in the cut. In these partial harvest cuttings, it is most important to retain trees of good vigor and form in order to maintain a growing stock that will rapidly increase in value in later years.

Two products that are especially desirable to harvest at this age are poles and piling, for which red pine is admirably suited (figs. 26 and 27). Piling usually commands the best prices of any product. A high degree of straightness is necessary to meet specifications but some knots are permitted. Consequently, in marking trees to be cut for poles and piling, it is possible to designate somewhat limby though straight trees which do not give promise of developing into the highest quality sawlogs. These high-value cuts are especially helpful from an economic standpoint because they go far toward liquidating the investment in growing the stand up to this point.

F-40930

FIGURE 26.—Skidding power poles in 80-year-old red pine stand. Only a small portion of the stand will be cut for poles. Cutfoot Experimental Forest.

RETURNS FROM AN OPERATION IN 80-YEAR-OLD TIMBER

Table 17 shows how partial harvest cuttings were carried out on two comparative plots (numbered 124 and 126) in 1940 in an 80-year-old stand in which there had been no previous treatment. On plot 124 (fig. 27), the purpose was to make a light cut of high-value piling and of sawlogs, marking trees largely in the upper crown classes. On plot 126 the object was to take out approximately the same volume but to confine the cutting to smaller and poorer specimens in order to favor the trees of highest potential for future crop trees. The piling derived in the second instance was entirely incidental—it was necessary

to salvage a few sleet-damaged trees. The greater stumpage returns from plot 124 despite a smaller volume in the cut shows the financial advantage of this type of cutting. Only 11 of the larger red pines, 12 inches d. b. h. and up, were cut per acre.

The argument is sometimes advanced that piling cuts of this sort represent "high grading" and will result in deterioration of the stand. As only those trees were selected which would cause the least opening or whose removal would be of the most benefit to the surrounding trees, it is believed that the future quality of the stand will not be impaired. Such cuttings, however, cannot be applied recklessly. There is obvious danger of "high grading" if caution is not exercised by the marker to keep the cut light. Since long piling usually brings twice as much per linear foot as short piling, it pays to hold piling trees for maximum size. By holding down the cut and saving all trees that are likely to increase sharply in value by putting on a little more diameter, it should be possible to make frequent light cuttings for piling or other high-grade material without reducing the growing capacity of the stand.


F-432998

FIGURE 27.—Red pine, because of its good form, makes an excellent piling tree. An 80-year-old stand from which the first piling cut has already been taken. Cut Foot Sioux District, Chippewa National Forest, Minn.

If the market could be depended upon, more profit could perhaps be made in growing red pine for piling than for any other product. The consumption of piling, however, is geared to heavy construction work such as bridge building, dock installations, and similar activities. Because such construction work fluctuates from year to year, the piling market should not be relied upon solely as the outlet for high-grade material.

TABLE 17.—*Returns per acre from partial harvest cuttings in 80-year-old red pine, 1940*

LIGHT CUT FROM ABOVE (PLOT 124)

Species	Volume [1]				Stumpage receipts [2]		
	Original	Cut		Left	Piling	Sawlogs	Total
		Piling	Sawlogs				
	Board feet	*Board feet*	*Board feet*	*Board feet*	*Dollars*	*Dollars*	*Dollars*
Red pine	12,743	976	836	10,931	17.53	5.02	22.55
Jack pine	2,864	257	1,561	1,046	3.20	5.46	8.66
Total	15,607	1,233	2,397	11,977	20.73	10.48	31.21

LIGHT CUT FROM BELOW (PLOT 126)

Species	Original	Cut: Piling	Cut: Sawlogs	Left	Piling	Sawlogs	Total
Red pine	11,010	382	1,231	9,397	6.86	7.39	14.25
Jack pine	3,259	253	2,329	677	3.15	8.15	11.30
Total	14,269	635	3,560	10,074	10.01	15.54	25.55

[1] Board feet, Scribner rule, for trees 7.6 inches diameter at breast height and larger to a 6-inch top diameter inside bark.
[2] Based on stumpage for piling of $0.04½ per linear foot for red pine and $0.03½ for jack pine ($17.96 and $12.45 per 1,000 board feet, respectively); and for saw timber of $6 and $3.50 per 1,000 board feet, respectively.

Because of the decreasing supply of good saw timber and the usual steady market for the better grades of lumber, saw logs offer more stability. Consequently, the reservation of a part of the stand for sawlog production would seem to be prudent business. At times when a variety of products may be sold, it is possible to carry on an integrated utilization that will make best use of all parts of the tree. A sawlog may be taken off as a butt cut, then a pole or piling stick, then a mine timber, and finally the top can be cut up into pulpwood.

REACTION OF A 100- TO 120-YEAR-OLD STAND TO PARTIAL HARVEST

After attaining an age of 90 or 100 years, height growth of red pine falls off but volume increment may continue to be good for a long period thereafter (table 11). Although this was not the case in an unmanaged stand at Cloquet, Minn. (*27*), in a managed stand (fig. 28) on the Chippewa National Forest very good growth has been obtained for a period of nearly 20 years following the first cut at age 100, with no sign of letting up.

In the first case no cutting was done, which may explain the poor growth after 80 years; in the latter instance three cuttings were made between 1926 and 1940, thus providing ample growing space and giving opportunity to eliminate the slower-growing trees and salvage those most likely to die.

The stand in which the Chippewa experiments were undertaken was a well-stocked mixture of red pine and jack pine with a small component of white pine. The red pine ranged from 3 to 15 inches diameter at breast height and the jack pine from 8 to 17 inches diameter at breast height. The average diameter of the stand was 9.5 inches. The site quality is medium for red pine. The basal areas shown in table 18 indicate the degree of cutting employed.

F-433000

FIGURE 28.—Red pine stand 120 years old which has received three light cuttings in the last 20 years. The stand is still growing at a rate of 400 to 500 board feet per acre annually. The reproduction is mostly white pine which was present as small seedlings before cuttings started. Bena District, Chippewa National Forest, Minn.

TABLE 18.—*Basal area per acre by degree of cutting in 100- to 120-year-old red pine, Cass County, Minn.*

Year	Basal area by degree of cutting—							
	Heavy (plot 1)		Moderate (plot 2)		Light (plot 3)		Very light (plot 4)	
	Before cutting	After cutting	Before cutting	After cutting	Before cutting	After cutting	Before cutting	After cutting
	Square feet	*Square feet*	*Square feet*	*Square feet*	*Square feet*	*Square feet*	*Square feet*	*Square feet*
1926	171	130	149	146	166	127	182	134
1931	138	43	145	70	130	89	143	120
1935	45	(1)	82	82	99	99	129	129
1940	(1)	(1)	95	92	111	107	138	132
1944	(1)	(1)	101	73	114	92	139	118

1 Clear-cut in 1935.

The first cutting in February, 1926, was a light to moderate improvement cutting which removed from 2 to 27 percent of the basal area. Jack pine was discriminated against in the marking. Since these cuttings did not provide good contrast between plots, another and much more severe cutting was carried out in 1931. This time the balance of the badly overmature jack pine was removed together with some of the red pine. In 1935 one plot was clear-cut but the others were not touched again until 1940 when a light salvage was made of wind-thrown timber. As a result of the frequent cuttings

given these plots, extraordinarily good growth has been made in a stand 100 to 120 years old.

The results on the four plots (table 19) give some interesting comparisons. Because of the good growth on plots 2, 3, and 4, where partial cuttings were made, it is obviously unwise to clear-cut stands of this character as was done in the case of plot 1. This plot, although restocked with reproduction, will not produce timber for many years. This experiment thus brings out the fallacy of clear-cutting at an age when, by proper management, the stand may be made to produce at a high rate, both in volume and value.

The stand on plot 4 tightened up somewhat but the general results were satisfactory. Plot 3 made the best showing, although its stocking was less than plot 4. The spacing maintained on plot 3 was open enough to permit elimination of the less thrifty trees. Only good growing trees were retained. It may be significant that during most of the period the basal area on plot 3 was in the neighborhood of 100 square feet per acre, which is much less than full stocking, according to yield table standards for fully stocked unmanaged stands, but which may be about optimum for management at this age (table 11).

TABLE 19.—*Total yield and annual growth in board feet*[1] *per acre by degree of cutting for 100- to 120-year-old red pine, Cass County, Minn.*

Item	Volume per acre by degree of cutting—			
	Heavy (plot 1)	Moderate (plot 2)	Light (plot 3)	Very light (plot 4)
	Board feet	*Board feet*	*Board feet*	*Board feet*
Original volume, 1926	24, 030	19, 189	22, 023	24, 941
Harvested, 1926–40	26, 757	10, 532	13, 663	12, 223
Stand, 1944	(2)	16, 607	17, 387	21, 357
Total yield to 1944 [3]	26, 757	27, 139	31, 050	33, 580
Growth per acre:				
1926–44 [4]	2, 727	7, 950	9, 027	8, 639
Per year	[5] 144	418	475	455

[1] Scribner rule for trees 7.6 inches diameter at breast height and larger to a 6-inch top diameter inside bark. Deductions made for mortality but not for defect. The trees on these plots (one-third acre each in size) ranged in diameter up to 17 inches.
[2] This plot clear-cut in 1935.
[3] That harvested plus residual stand present in 1944.
[4] Difference between total yield and original volume.
[5] During the whole 19-year period. Before clear-cutting this plot grew at the rate of 273 board feet per acre annually.

Assuming a stumpage value of $10 per thousand board feet, plot 3 has yielded $4.75 per acre per year in gross returns for the past 19 years. This is based entirely on sawlog utilization without regard to any pulpwood that may have been produced in tops or small trees, or to higher valued products such as piling. The mean annual growth of plots 2, 3, and 4 averaged together, from the time they were placed under management in 1926 until 1944, has been 449 board feet per acre per year, or nearly twice the rate for the first 100 years of the life of the stand.

Since the stand shows no sign of slowing down in growth, it is reasonable to expect the continuance of a good rate of increment of high-quality material for another 20 years provided marking is carefully done to preserve the most thrifty trees at well-spaced intervals.

With this thought in mind, another light cutting was made in the stand in 1944, taking out from 3,200 to 4,700 board feet per acre on the several plots.

QUALITY GROWTH DURING LATER YEARS OF ROTATION

The increase in board-foot volume as shown by the data for the plots just described does not illustrate fully the advantage of growing timber to larger sizes. There is a value increment as well as a volume increment as timber increases in size and the value increase is the more rapid. This was clearly brought out by Jensen and others (*16*) for white pine in New England. They show graphically that lumber values increase steadily from trees 6 inches diameter at breast height to about 14 inches, then less rapidly until about 20 inches, after which there is very little value increase per unit of volume with greater diameter.

At the same time, logging and milling costs decrease as the timber gets larger. It seems probable that red pine would similarly rise in value in Minnesota. There is also an additional value increase for red pine that can be used for large piling (fig. 29) as suggested in a previous section.

F-433002

FIGURE 29.—A 140-year-old mixed red pine-white pine stand following a light cut. Note piling in foreground. Marcell District, Chippewa National Forest, Minn.

MAKING THE FINAL HARVEST AND STARTING THE NEW CROP

Beginning at about age 120, consideration should be given to reproducing the stand. As brought out earlier, red pine, if opened up enough to permit good crown development, begins to bear ap-

preciable quantities of seed after it reaches an age of about 80 years. Just how much seed is produced by a stand of this age is not known. An older stand was found to disperse 75,000 to 100,000 seed per acre during a 15-day period in the fall of 1930 (*33*). Seed normally falls in October. There are cases of record, however, following a cool, wet summer, where seed is not dispersed until winter (*30*).

IMPORTANCE OF ADVANCE REPRODUCTION

If the stand has been properly cared for previously it is quite likely that the problem of reproduction will have been at least partially solved by the time the stand reaches age 120. With periodic seed years at 3- to 5-year intervals fairly well assured and gradual opening up of the stand by light partial harvest cuttings, a stocking of advance reproduction is built up. A 120-year-old stand, having a volume of 18,000 board feet per acre on Pike Bay, Chippewa National Forest, which had received very light periodic cuts every 5 to 8 years for at least the preceding 20 years, will serve to illustrate this point (table 20).

This stand is well stocked with reproduction of several age classes, thus indicating that seeding took place over a considerable period of years but mostly since cutting started. These cuttings do not need to be heavy for, as shown by Shirley (*32*), any light value higher than 35 percent is ample for the establishment of red pine reproduction. The seeding-in may be accentuated if the trees happen to be distributed somewhat group-wise so that there is more room for reproduction. Such grouping of trees seems to occur naturally without conscious effort in marking to create openings.

TABLE 20.—*Distribution of advance reproduction by age classes in 120-year-old red pine following light periodic cutting for 20 years*

Species	Seedlings per acre	Distribution of reproduction by age classes					Total
		1–5 years	6–10 years	11–15 years	16–20 years	21–25 years	
	Number	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Red pine	1,300	6	11	17	2	2	38
White pine	1,250	9	6	13	4	4	36
Jack pine	900			7	18	1	26
Total	3,450	15	17	37	24	7	100

Where the stand has not been gradually opened up as recommended, there is likely to be a strong representation of white pine in the advance reproduction if seed trees are present. Observations near Bena, Minn., in a well-stocked stand having a basal area of from 150 to 180 square feet per acre, illustrate how white pine may become established beneath red pine if the density is high. When first examined in 1923, the ground underneath this stand, then about 95 to 100 years old, was well carpeted with 2,000 to 6,000 white pine seedlings per acre 2 to 4 inches high. Yet, white pine made up only about 8 percent of the trees in the overstory. Since 1926, this stand has been given four partial harvest cuttings (table 18).

The results of the cuttings in terms of reproduction on three plots are shown in tables 21 and 22. There was some loss of seedlings due chiefly to logging damage, but the present stocking is more than ample. White pine still predominates although the proportion of red pine is slightly higher now than in 1926. Had the cuttings been started earlier, there would have been a higher proportion of more desirable red pine. The growth of seedlings has been quite satisfactory and more or less in proportion to the degree of cutting (table 22). The overstory should now be removed in about three shelterwood cuttings over a period of about 20 years to bring through the advance reproduction and to maintain the previous good volume growth (table 19) as long as possible. Extreme care must be used in these removal cuttings to prevent excessive damage to the reproduction, especially to the larger and more promising saplings. With reproduction 5 to 10 feet tall, snow is no protection and heavy breakage of saplings will occur if logging is undertaken during freezing weather. Summer logging will probably give better results due to greater limberness and flexibility of the small trees during the growing season and will stir up the soil, thus encouraging more red pine seedlings to start.

TABLE 21.—*Total seedlings per acre by degree of cutting and species in 100- to 120-year-old red pine, Cass County, Minn.* [1]

Year	Moderate cutting (plot 2)				Light cutting (plot 3)				Very light cutting (plot 4)			
	Total seedlings	White pine	Red pine	Jack pine	Total seedlings	White pine	Red pine	Jack pine	Total seedlings	White pine	Red pine	Jack pine
	Number	*Percent*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*	*Percent*
1923	2, 001	67	21	12	2, 124	95	2	3	5, 989	94	5	1
1926	1, 878	70	20	10	1, 797	96	2	2	4, 778	93	5	2
1927	1, 960	73	17	10	1, 960	94	3	3	5, 309	94	4	2
1928	2, 069	70	19	11	2, 164	96	3	1	5, 622	94	5	1
1929	1, 729	75	16	9	2, 410	96	2	2	5, 622	94	5	1
1930	1, 879	72	17	11	2, 872	96	2	2	6, 098	93	5	2
1931	1, 184	75	16	9	1, 674	94	3	3	4, 873	92	5	3
1932	1, 511	60	13	27	1, 919	82	6	12	4, 955	88	6	6
1944	979	73	17	10	1, 648	92	7	1	4, 724	93	6	1

[1] As determined from 3,200 square feet of counting strip on each plot. Cuttings were made in 1926, 1931, 1935, and 1940.

TABLE 22.—*Average height of seedlings, by degree of cutting, under 100- to 120-year-old red pine* [1]

Year	Moderate cutting (plot 2)			Light cutting (plot 3)			Very light cutting (plot 4)		
	White pine	Red pine	Jack pine	White pine	Red pine	Jack pine	White pine	Red pine	Jack pine
	Feet	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*	*Feet*
1923	0. 3	0. 3	0. 8	0. 3	0. 2	0. 3	0. 3	0. 3	0. 7
1926	. 4	. 5	. 9	. 4	. 4	. 4	. 4	. 4	. 8
1930	. 9	. 7	1. 7	. 6	1. 3	. 8	1. 2	1. 2	1. 4
1944	6. 9	5. 0	15. 1	4. 0	9. 9	4. 7	1. 3	1. 3	7. 5

[1] Stand under management since 1926 near Bena, Cass County, Minn. Cuttings were made in 1926, 1931, 1935, and 1940.

SHELTERWOOD CUTTING TO START REPRODUCTION

In the absence of advance reproduction in stands approximating 120 years in age, definite steps should be taken to obtain it. The best thing to do is to make a summer shelterwood cutting of one-third to one-half the volume during a seed year or immediately after one. From a practical logging standpoint, however, as was pointed out in the discussion of the two-cut method, it may not always be possible to schedule cutting of mature stands only during seed years, because of their irregularity. In such cases, it will probably be advisable as an alternative to open up the stand more cautiously, taking out about one-fourth the volume in the first cut, and to defer the second cut until after a seed year. Such treatment may not reproduce the area so quickly and is more conducive to establishment of white pine than of red pine but it is not so likely to create conditions favorable to brush invasion. In either case, there would be two or three shelterwood cuttings before the final removal cut at about 140 years (figs. 30, 31, 32).

F-433004

FIGURE 30.—Red pine stand 140 years old with reproduction well established in groups. Although the stand has had two light cuttings, the group-wise character of the old stand is largely the result of natural occurrence.

Fortunately, a good deal of flexibility is possible in timing the final harvest cutting of red pine. On good sites the stand may be making too great an annual increment to warrant cutting at 140 years, or some especially large timber may be desired. In either case, it may be good business to hold it longer; it must be remembered that red pine is long-lived and disease-resistant, hence it does not have to be harvested at any exact age for fear of loss.

F-433005

FIGURE 31.—Red pine 140 years old after several light shelterwood cuttings. Reproduction is well established. Growth on the residual stand is still good because only trees with good crowns are left. Williams' Narrows, Chippewa National Forest, Minn.

F-392286

FIGURE 32.—By holding the best trees in the overstory, the gap between the final harvest of the old forest and the coming merchantability of the new one may be bridged. In this red pine stand, the overstory is being removed very gradually and is now ready for a final cut. Pike Bay, Chippewa National Forest, Minn.

ARTIFICIAL AIDS TO NATURAL REPRODUCTION

Premature opening of a stand by storm action may result in brush encroachment to the exclusion of natural reproduction. Where brush has taken over the ground artificial means are required to restock the site. Some preliminary experiments to determine the effectiveness of ground scarification in promoting natural reproduction were undertaken in 1930 (*33*). An ordinary farm disk drawn by a crawler tractor was used to stir up the soil underneath an old-growth red pine stand during a good seed year. Although the machine exposed mineral soil in areas of light ground cover fairly effectively, it was not heavy enough to turn under sod and was totally inadequate for tearing up brush. Yet where the soil had actually been disked, there were over 10,000 seedlings per acre 2 years after treatment, 12 times as many as were found on undisked areas. Prompt removal of a part of the overstory would have insured a good stocking of red pine seedlings.

Where the undergrowth of brush is dense, use of much heavier equipment such as the Athens type disk plow is advocated (fig. 33). This has been successfully used in scarifying ground in order to reproduce jack pine (*13*). Promotion of natural reproduction through scarification is, of course, most effective in good seed years which occur on the average only one year in four.

An example of successful scarification with the Athens disk plow after the cutting of a mixed jack pine-red pine stand on the Chippewa National Forest is of special interest at this point. The badly overmature jack pine which made up the bulk of the stand was cut in 1941. Twenty-five 8- to 12-inch red pines per acre were left along with an equal number of jack pines. An undergrowth of brush prevented any reproduction from starting at the time of logging so the area was disked in the summer of 1944. It was noticed that during the 3 years between cutting and disking the crowns of the red pines had filled out appreciably and that they bore many cones in 1944. In the fall of 1945 following a good spring and summer growing season a count on 40 milacre quadrats showed 3,575 red pine and 3,375 jack pine seedlings per acre. Ninety-two percent of the quadrats were stocked with red pine. General observations on the area in 1946 indicated the seedlings to be well established.

Although, in the illustration cited, the results were remarkably good, supplemental planting of red pine transplants is a surer method of restocking brush-covered sites. The Athens disk has been found to be a particularly effective tool for preparing brushy areas for planting. Without some such ground preparation, planting on brushland is futile. Cross-disking of the brush, which consists of two diskings, the second at right angles to the first, in midsummer turns up the roots of the shrubs and sets back their growth for several years—long enough for the planted trees to get a good start.

Disking has been more successful as a means of ground preparation in dense brush than has furrowing with a heavy plow. Red pine transplants after 2 years in the field were 50 percent taller on disked areas than in plowed furrows. The poorer growth in the furrows is attributed mainly to lower soil fertility in the furrow bottoms. Moreover, the plants on disked areas, besides having more fertile top soil to start in, are set several inches to a foot higher and thus have a

F-365611

Figure 33.—Athens type disk plow drawn by crawler tractor preparing ground for reproduction of jack pine. This is the type of equipment advocated for scarifying brushy red pine sites.

further comparative advantage in competing with the brush. Thorough disking may require up to two tractor hours per acre.

Because disking is expensive, prescribed burning as a silvicultural measure to prepare a seedbed has been suggested as worthy of trial. It seems quite probable that burning off the brush would aid reproduction if done immediately before a good seed year; at least this has happened at times in nature (fig. 5). No comparative cost data are available. The cost of burning, however, would also likely be high because of the necessity of special protection to keep the fire from getting out of hand. Experimentation is needed to learn the possibilities.

SLASH DISPOSAL UNDER INTENSIVE MANAGEMENT

Frequent light thinnings and intermediate cuttings recommended under intensive management create no heavy slash. What there is lies in the shade where it stays moist and rots fairly soon. Therefore, so far as fire protection is concerned, no disposal of such slash would seem necessary. Neither is it heavy enough to be much of an impediment to regeneration, although occasionally it may be advisable to scatter a little of it that happens to fall on a patch of good reproduction.

Slash burning is not recommended unless cuttings exceed one-third the volume of a heavy mature stand. Final harvest cuttings in some instances may take out one-third to one-half the volume of a stand or 8,000 to 10,000 board feet per acre. In heaving cuttings of this sort, accumulations of slash increase fire hazard and may smother reproduction if some of it is not moved or disposed of. If logging is done in winter, progressive or "swamper" burning is the best practice as described under seed-tree cuttings. Heavy slash resulting from summer cutting should be piled during logging and later burned while snow is on the ground. Complete disposal of all slash should rarely be necessary. The methods recommended can be carried out with expenditures of $0.75 to $1.00 per M board feet (1942 rates).

Recapitulation of Cutting Recommendations Under Intensive Management

Age classes

20–30 *Noncommercial thinning.*—If the stand at this age contains over 2,000 stems per acre or appears overdense as a whole or in spots, a thinning to 5- to 5.5-foot spacing is desirable. The purpose of this thinning is to prevent a slowing down of growth rate and to hasten the time for the first commercial thinning. Any pruning contemplated should be started at this time. About 100 fast-growing crop trees per acre should be sufficient to prune. This first pruning should not sever branches for more than one-half the height of the tree. Pruning is more necessary in understocked stands than in well-stocked stands if quality timber is to be grown. At age 30, a stocking of 1,100 trees per acre is recommended for average sites.

30–40 *Commercial thinning.*—The purpose of this thinning is to improve the growing space for all trees in the stand. The cut should be made mostly from below, except when jack pines are present. Where these appear to interfere with growth and development of promising red pines, they should be cut regardless of size. Pruning of selected trees to a height of 16 feet should be completed during this period. The products removed in thinning will be mostly pulpwood and fence posts. One or two thinnings in well-stocked stands should be possible during this period. A growing stock of about 830 trees per acre is recommended at age 40 for average sites.

40–80 *Improvement cuttings.*—During this period cuttings should be made for the primary purpose of molding the stand into the best possible shape to grow high-value products in the future. The cuttings should be made mostly, but not entirely, from below, removing trees which appear to be of low future value and those which interfere with the growth and development of crop trees and other trees of high future value. The products removed will be pulpwood, fence posts, box bolts, and possibly a few small poles. In each of these cuts it should be borne in mind that the trees, if growing well, might develop into higher-grade products by the time of the next cut. Judicious care must, therefore, be exercised in the marking. The emphasis should always be on the growing stock left, rather than on the products taken out in each cut. Improvement cuttings at 5- to 10-year intervals appear feasible. Stockings of 620, 470, and 350 trees per acre are recommended for ages 50, 60, and 70. At age 80, the stand should contain about 270 well-developed trees per acre, on average sites.

Age classes

80–120 *Intermediate harvest cuttings.*—The stand under management is now ready to yield light partial cutting of high-value products such as piling and larger poles. Before marking these products the forest manager should, however, select his final crop trees and always favor these in future cuts. Large, limby trees and other trees which interfere with crop-tree development or the growth of smaller, well-formed trees may then be cut for piling. Poles may be cut from dense groups of smaller trees. Harvesting of these products at 5- to 10-year intervals must proceed cautiously so as not to open the canopy prematurely and thus invite brush invasion which will later hinder regeneration. On average sites stockings of 220, 180, and 150 trees per acre are recommended for ages 90, 100, and 110. At age 120 the stand should contain approximately 120 well-developed crop trees per acre.

120–130 *Regeneration cuts.*—During this period, the primary object of management is regeneration of the stand by shelterwood cuttings. Cuttings should consist of removing in several operations all but the final crop trees—about 50—which will then form a shelterwood. Trees cut will make piling, poles, and small saw timber. When reproduction has been established, at about age 130, half of the final crop-tree volume should be removed for piling and high-grade saw timber in order to provide the light needed to develop the reproduction. If regeneration has not taken place by age 130, artificial aid should be resorted to. Disking during midsummer of a good seed year is one such method. Supplemental planting may occasionally be required to achieve satisfactory regeneration.

140 *Final cut.*—At this age the stand should be two-storied. The remaining crop trees may now be removed, preferably in two operations. In some cases it may be desirable to leave a scattered overstory to an even later age for especially high-value growth or because of incomplete regeneration.

SUMMARY

Red pine, once an important component of the famous virgin pine forests of Minnesota, now present chiefly as second growth, has good potentialities for forest management. It makes fairly rapid growth, is comparatively free from insect pests and diseases, and produces high-grade timber. The present rather restricted area of red pine is being expanded through forest planting. Cutting experiments and demonstrations were started in 1926 and large-scale tests of timber management date back over 40 years. The results presented here cover (1) seed-tree cuttings, (2) two-cut shelterwood methods, and (3) more intensive forest practice which provides for frequent light thinnings and intermediate cuttings followed by shelterwood cutting near the end of the rotation.

Experience in managing red pine began with the passage of the Morris Act of 1902, which established the Chippewa (then Minnesota) National Forest and prescribed the leaving of seed trees in the original logging. These seed-tree cuttings as they were applied to red pine had many shortcomings, but were responsible in part for the generally well-stocked condition of logged-off lands where fire did not destroy advance growth. The application of the seed-tree method was the first large-scale effort to conserve red pine and paved the way for more intensive practices to follow.

Two-cut shelterwood cuttings have been practiced on a moderate scale with quite satisfactory results. Under such a method there is less danger of brush invading the site and considerably more assurance of getting satisfactory reproduction than under the seed-tree method. Moreover, growth per acre of merchantable wood between the time of the first cut and the removal of the stand is much greater than under the seed-tree method, a point of considerable significance when

the interval between cuts is as long as 15 or 20 years. To obtain satisfactory growth the method must be applied before the stand loses its vigor.

Intensive forest management which calls for frequent thinnings and light improvement cuttings is far superior to a two-cut system and is generally feasible in red pine because of good markets and accessibility of the region where it occurs. A variety of forest products, including pulpwood, box bolts, mine timbers, poles, piling, and sawlogs, is usually in demand. Pruning is recommended for production of clear lumber. Early thinning, as shown by tests in overdense sapling stands, will shorten rotations. Thinnings in 40-year-old or younger stands for pulpwood pay their way and improve the forest.

Light intermediate cuttings in middle-aged stands are shown to be profitable operations. Moreover, when properly carried out, they improve the stand. By making such cuttings at 5- to 10-year intervals, weak trees are salvaged before they die and remaining trees are provided with adequate growing space. Through such practice, more high-quality timber is grown and yields are greatly increased, thus providing the owner with far greater returns than under a two-cut system. Yield tables are presented for managed and unmanaged stands. The much greater cumulative yield from managed stands is presented graphically.

Some advance reproduction may build up in red pine after age 80 as partial harvest cuttings begin, but no special efforts to regenerate the stand need to be made prior to age 120. Shelterwood cuttings are then recommended. If possible these should be made during a good seed year which occurs on the average of one year in four. If brush is heavy, scarification with an Athens disk plow and supplemental planting may be required. By keeping the stand fairly open during the later years of the rotation, the regeneration is allowed to develop. Ample growing space also makes it possible for the overstory to maintain good growth until an age of about 140 years is reached. The final cut should then be made.

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APPENDIX

Tables 23, 24, 25, and 26 prepared by S. R. Gevorkiantz will be found useful in estimating contents of standing trees of red pine in board measure and in cords.

Table 23.—*Board-foot volume, Scribner rule, of red pine grown in well-stocked stands* [1]

Diameter breast high (inches)	Volume by number of 16-foot logs [2]—						Basis, trees [3]
	1	2	3	4	5	6	
	Board feet	*Board feet*	*Board feet*	*Board feet*	*Board feet*	*Board feet*	*Number*
8	13						12
9	20	35					25
10	28	49					18
11	36	64	88				21
12	46	82	112				15
13	57	102	140	166			13
14	69	122	168	202			10
15	81	144	201	238			15
16	94	169	235	279	330		9
17	109	195	269	324	376		11
18	124	222	309	372	436	475	8
19	140	250	348	420	493	540	6
20	157	281	393	473	556	615	8
21	175	314	440	532	623	695	3
22	193	348	486	589	687	775	4
23	215	380	540	645	762	865	
24	238	418	585	710	840	965	
25	260	460	645	775	910	1,055	
26	285	495	700	845	990	1,150	
27	310	540	760	920	1,080	1,260	
28	340	590	820	990	1,160	1,350	
29	370	640	880	1,060	1,255	1,475	
30	400	690	950	1,145	1,355	1,590	

[1] Based on table 104, Volume, Yield, and Stand Tables for Tree Species in the Lake States (*5*). Volume is gross above stump (straight and sound basis) of usable sawlogs. Heavy lines indicate limits of basic data.
[2] Usable length. Top diameter variable, not less than 6 inches inside bark. Stump height, 1 foot for diameters less than 12 inches; 1.5 feet, for diameters from 12 to 18 inches; 2 feet, for diameters over 18 inches.
[3] Total: 178.

TABLE 24.—*Board-foot volume, Scribner Decimal C rule, second-growth red pine* [1]

Diameter breast high (inches)	Volume by total height in feet—										Basis, trees
	30	40	50	60	70	80	90	100	110	120	
	10 board feet	*10 board feet*	*10 board feet*	*10 board feet*	*10 board feet*	*10 board feet*	*10 board feet*	*10 board feet*	*10 board feet*	*10 board feet*	*Number*
7	------	1	1	2	2	------	------	------	------	------	18
8	1	2	2	3	4	5	------	------	------	------	23
9	1	2	3	5	6	7	8	------	------	------	18
10	2	3	5	6	8	9	10	12	------	------	27
11	2	4	6	8	9	11	13	15	------	------	22
12	------	5	7	9	12	14	16	18	------	------	14
13	------	6	8	11	14	16	19	21	------	------	10
14	------	------	10	13	16	19	22	25	28	------	11
15	------	------	12	15	19	22	26	29	33	------	12
16	------	------	13	17	21	26	30	33	37	------	9
17	------	------	15	19	24	29	33	38	42	------	10
18	------	------	------	22	27	32	37	42	47	------	7
19	------	------	------	25	30	36	42	47	52	------	3
20	------	------	------	27	34	40	46	52	58	64	7
21	------	------	------	------	37	44	50	57	63	69	5
22	------	------	------	------	40	48	55	62	69	75	2
23	------	------	------	------	44	52	60	68	75	82	------
Basis, trees (number)	5	14	52	17	25	30	31	22	2	------	198

[1] Data from Vilas, Oneida, and Bayfield County survey (*5*). Stump height, 1 foot; top diameter inside bark, 6 inches. Compiled at the Lake States Forest Experiment Station by the alinement-chart method Heavy lines indicate extent of data. Aggregate deviation, 0.1 percent. Average deviation, ± 8.6 percent.

TABLE 25.—*Unpeeled merchantable volume, in standard cords, of red pine*

Diameter breast high (inches)	Volume [1] by number of 8-foot bolts—							
	1	2	3	4	5	6	7	8
	Cords	*Cords*	*Cords*	*Cords*	*Cords*	*Cords*	*Cords*	*Cords*
5	0.01	0.02	------	------	------	------	------	------
6	.02	.03	0.04	0.06	------	------	------	------
7	.02	.04	.06	.07	0.09	------	------	------
8	.03	.05	.07	.09	.12	0.14	------	------
9	.04	.06	.09	.11	.14	.17	------	------
10	.05	.07	.10	.13	.17	.20	0.24	0.29
11	.06	.09	.12	.15	.19	.23	.28	.32
12	.07	.10	.14	.18	.22	.27	.32	.36
13	.08	.12	.16	.20	.26	.31	.37	.42
14	.09	.13	.18	.23	.29	.35	.42	.47
15	------	------	.20	.26	.32	.39	.47	.53
16	------	------	.22	.29	.36	.44	.52	.59
17	------	------	.24	.32	.40	.48	.58	.65
18	------	------	.27	.35	.44	.53	.63	.72
19	------	------	.29	.38	.48	.58	.69	.78
20	------	------	.32	.42	.52	.63	.75	.85
21	------	------	------	.45	.57	.68	.82	.92
22	------	------	------	.49	.61	.74	.88	.99
23	------	------	------	------	.66	.80	.95	1.07
24	------	------	------	------	------	.85	1.02	1.15
25	------	------	------	------	------	.91	1.09	1.23

[1] Volume of main stem above 1-foot stump to usable top; i. e., the point at which merchantability is limited by branches, deformity, or a diameter less than 4 inches inside bark.

The heavy demand for pulpwood during recent years has established the practice of using trees to smaller top diameters. This sometimes makes existing volume tables too conservative as may be the case with table 25. Table 26 indicates the additional volume of pulpwood attained when utilization is changed from a 4-inch to a 3-inch top diameter inside bark.

TABLE 26.—*Percent of additional volume of pulpwood when top diameter utilization is changed from 4 inches to 3 inches inside bark* [1]

Diameter breast high (inches)	Additional volume to 3-inch top, by number of 8-foot bolts—				
	2	3	4	5	6
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
5	28				
6	23	16	12		
7	17	12	10	8	
8		10	8	6	5
9		8	6	5	4
10			5	4	3
11			4	3	3
12			4	3	2

[1] Not to be used on trees where merchantability to 4-inch top is limited by defect or deformity.

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